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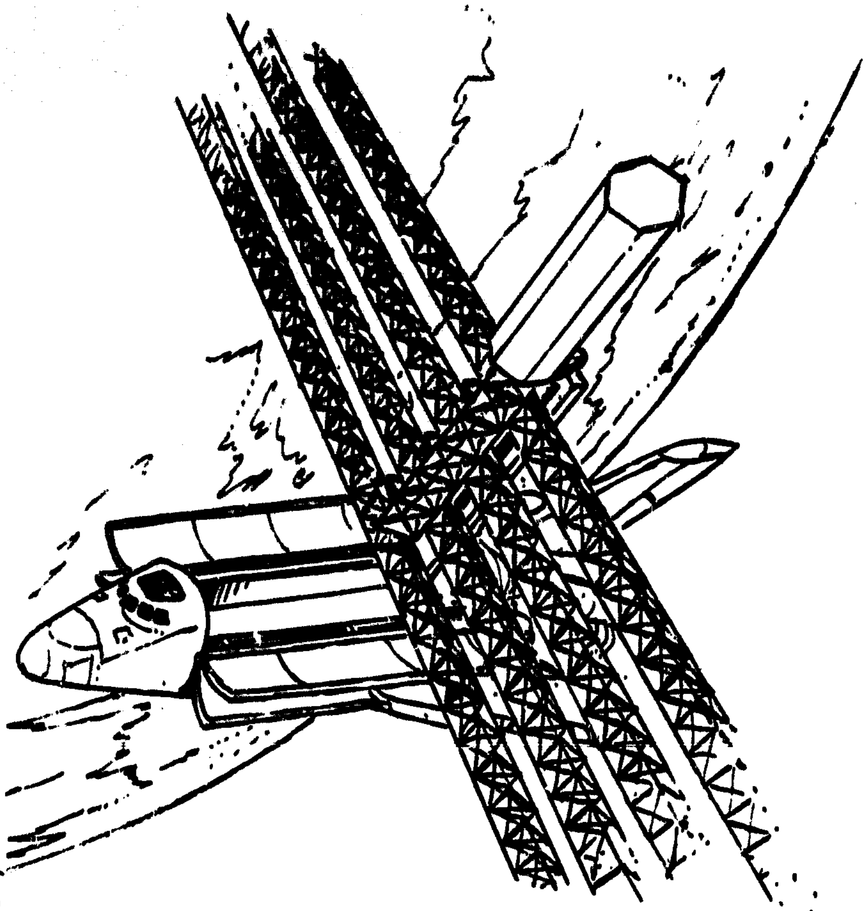

SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS) PART III

FINAL REPORT
VOLUME III • REQUIREMENTS

CONTRACT NO. NAS9-15310
DRL NO. T-1346
DRD NO. MA-664T
LINE ITEM NO. 3

GENERAL DYNAMICS
Convair Division

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San Diego, California 92138
Advanced Space Programs

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SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS) PART III

FINAL REPORT

VOLUME I ✦ EXECUTIVE SUMMARY
VOLUME II ✦ STUDY RESULTS
VOLUME III ✦ REQUIREMENTS

CASD-ASP78-016

SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS) PART III

FINAL REPORT

VOLUME III • REQUIREMENTS

CONTRACT NO. NAS9-15310
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LINE ITEM NO. 3

29 June 1979

Submitted to
National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas 77058

Prepared by
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FOREWORD

This final report was prepared by General Dynamics Convair Division for NASA-JSC in accordance with Contract NAS9-15310, DRL No. T-1346, DRD No. MA-664T, Line Item No. 3. It consists of three volumes: (I) a brief Executive Summary; (II) a comprehensive set of Study Results; and (III) a compilation of Requirements.

The principal study results were developed from August 1978 through April 1979, followed by final documentation. Reviews were presented at JSC on 13 December 1978 and 24 April 1979, and at NASA Headquarters on 17 May 1979.

Due to the broad scope of this study, many individuals were involved in providing technical assistance. General Dynamics Convair personnel who significantly contributed to the study include:

Study Manager	Lee Browning
Mechanical Design	John Bodle, Steve Hardy, Hans Stocker
Avionics & Controls	Jack Fisher, Ed Kleidon, Bill Snyder, Doug Burgess
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Structural Dynamics	Des Pengelley, Shih-How Chang
Thermodynamics	Dick Pleasant
Mass Properties	Dennis Stachowitz
Mfg. Technology	Steve Hardy
Economic Analysis	Bob Bradley
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The study was conducted in Convair's Advanced Space Programs department, directed by J. B. (Jack) Hurt. The NASA-JSC COR is Lyle Jenkins of the Spacecraft Design Division, under Allen J. Louviere, Chief.

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SCOPE

(DER

This document defines the performance, design, and verification requirements for the Space Construction Automated Fabrication Experiment (SCAFE).

The source of each imposed or derived requirement is identified by the abbreviations enclosed in parentheses in the margin adjacent to the requirement.

Abbreviations that identify the sources are defined as follows:

Abbreviation	Source
DER	Derived Requirement
FSSR-C	Functional Subsystem Software Requirements, GN&C; Part C, Flight Control on Orbit, Rockwell Report No. SD 76-SH-0009, dated 1 June 1977
JSC-ICD -2-19001	Shuttle Orbiter/Cargo Standard Interfaces.
IRAD, K	IRAD 111-4770-080, Prelim Design Requirements for Beam Builder
JSC 07700	Space Shuttle System Payload Accommodations, JSC 07700, Vol. XIV, Revision F, Change No. 26.
JSC-10615	Shuttle EVA Description and Design Criteria, JSC-10615, dated May 1976.
JSC 11568	Initial Technical, Environmental and Economic Evaluation of Space Solar Power Concepts, Report JSC 11568, dated 31 August 1976.
PROP.	SCAFE Proposal
SOW	Statement of Work
SPAH	Spacelab Payload Accommodation Handbook, ESA SLP/2104, PDR-B, 1976.
U.H.	STS User Handbook

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APPLICABLE DOCUMENTS (DER)

The following documents are included to provide guidance in defining the design, development, and mission operations phase of the SCAFE Program. This list will be maintained and updated as the program matures. The list contains specifications, standards, and other requirements that are representative of those that will be imposed in later program phases. Consequently, and to the extent practicable, they should be considered during preliminary design and program definition.

2.1 SPECIFICATIONS

MIL-D-1000	Drawings, Engineering and Associated Lists.
MIL-B-5087(2)	Bonding, Electrical and Lightning Protection, for Aerospace Systems.
MIL-E-6051D(1)	Electromagnetic Compatibility Requirements, Systems.
MIL-M-38310B	Mass Properties Control Requirements for Mission and Space Vehicles.

2.2 STANDARDS

MIL-STD-100A	Engineering Drawing Practices
MIL-STD-143B	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-461A	Electromagnetic Interference Characteristics, Requirements for
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-463	Electromagnetic Interference Definitions and System of Units.
MIL-STD-1472B	Human Engineering Design Criteria for Military Systems, Equipment and Facilities.
MIL-STD-810B	Environmental Test Methods
MIL-STD-1512	Electro-Explosive Subsystems, Electrically Initiated, Design Requirements and Test Methods.

2.3 OTHER PUBLICATIONS

NHB 5300.4(3A)	Requirements for Soldered Connections.
NHB 6000.1(1A)	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment and Associated Components.
NASA SP208	The Prevention of Electrical Breakdown in Spacecraft
JSC-11123	STS Payload Safety Guidelines Handbook.
JSC-10615	Shuttle EVA Description and Design Criteria.
K-STSM-14.1	KSC Launch Site Accommodations Handbook for STS Payloads.
JSC-08060	Space Shuttle System Pyrotechnic Specification
NHB-8060.1A	TBD
JSC SPR0022	TBD
JSC SC-L-002	Functional Design Requirements for Lightning, Manned Spacecraft and Related Flight Crew Equipment, 25 July 1972.
JSC SC-F-0006	Manned Spaceflight Extravehicular/Intravehicular Activity Support Equipment, Functional Design Requirements for, General Specification, December 1972.
JSC-ICD-2-19001	Shuttle Orbiter/Cargo Standard Interfaces
JSC-07700, Vol XIV	Space Shuttle System Payload Accommodations Rev. F, Sept. 22, 1978.
MSFC-STD-512A	Man/System Requirements for Weightless Environments, 1 Dec 1976.

3

REQUIREMENTS

3.1 SCAFE PROGRAM DEFINITION (SOW 2.0)

The SCAFE Program shall define, develop, and demonstrate the techniques, processes, and equipment required for the automatic fabrication of structural elements in space and for the assembly of such elements into a large, lightweight structure. The program shall define a large structural platform to be constructed in orbit using the space shuttle as a launch vehicle and construction base.

The following programmatic guidelines shall be observed: (SOW 4.1)

a. The development of automatic fabrication of structure will be fundamental to the SPS development program.

b. The space construction experiment shall be compatible with the operational Space Transportation System (STS). Specific considerations are Orbiter landing center of gravity constraints, Orbiter payload bay envelope, payload bay accommodations, STS performance capability, and STS launch turnaround.

c. The space construction experiment shall be constructed and operated with one STS flight.

d. Revisit as a mission option would occur within three months.

e. Crew EVA capability in support of the space construction experiment will be provided by the nominal four-person crew of the STS.

3.1.1 GENERAL DESCRIPTION. Application of automated construction techniques is a logical step in technology advancement in support of the construction of large platforms in space. The concept emphasizes a beam builder for fabrication of basic truss elements from preprocessed, prepackaged stock material. Other aspects of construction must also be exercised in order to complete the platform. The structural platform defined in Figure 3-1 will be used as a reference configuration. (SOW 3.0)

The trusses are to be automatically fabricated by a beam builder machine. The trusses are held in position by the assembly fixture while the attachments between truss sections are completed. Measurement of structural response of the platform is to be part of a test program which will follow construction of the platform.

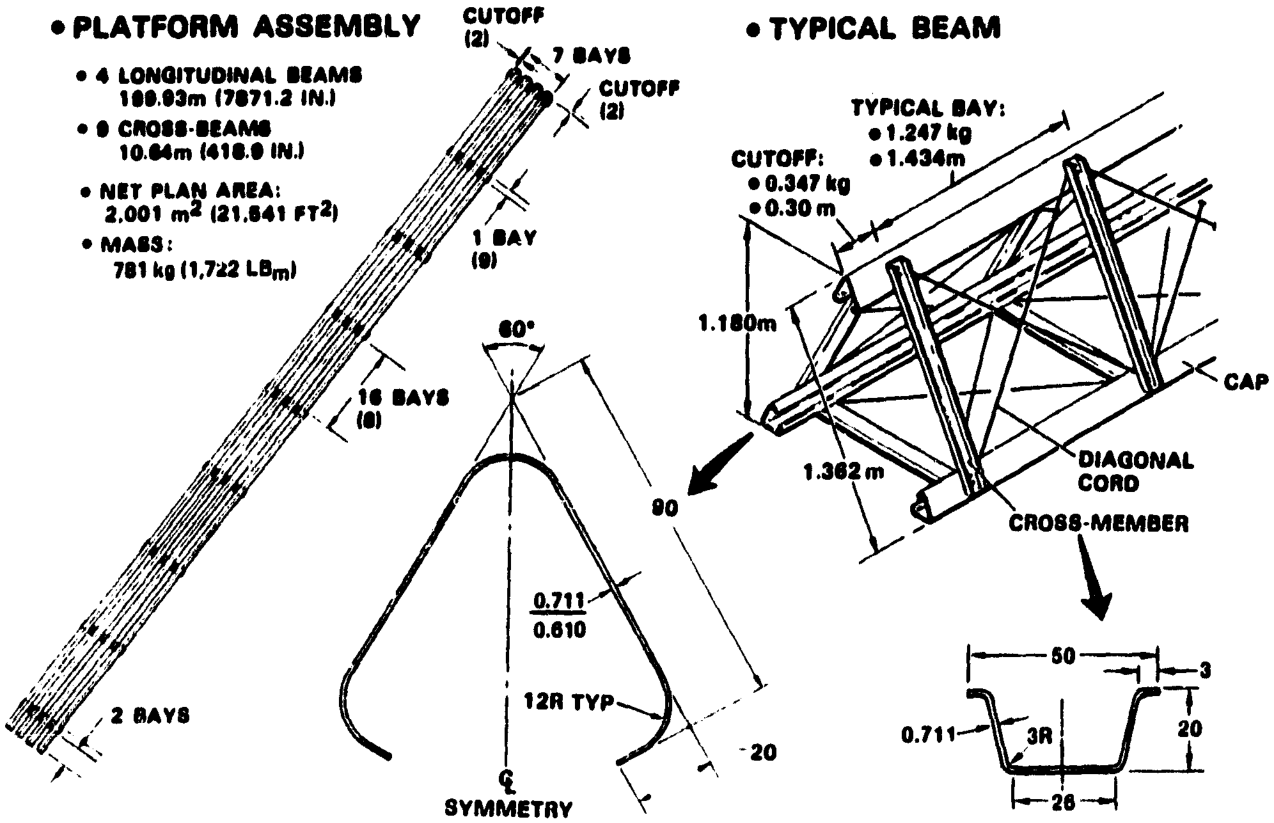

Figure 3-1. Structural platform concept - reference configuration.

(DER) 3.1.1.1 Program Elements. A list of SCAFE program elements, identified by their WBS element code numbers is given below. Refer to the Work Breakdown Structure in Paragraph 3.1.5.1 for detail description.

1100	Flight Hardware
1200	Systems Engineering & Integration
1300	System Test
1400	Ground Support Equipment (Peculiar)
1500	Support Operations
1600	Ground Operations
1700	Mission Operations
1800	Facilities and Equipment
1900	Program Management and Administration

3.1.2 MISSIONS. All SCAFE program objectives will be accomplished with one flight. As stated in the programmatic guidelines, the space construction experiment shall be constructed and operated on this flight. The operation of the experiment will include dynamic and thermal response tests. In addition, a separation and recapture test will be performed as a prelude to an optional revisit flight. During the first flight, scientific experiment equipment and subsystems to operate all experiments will be installed on the platform. A nominal seven-day mission should be the required duration to meet these objectives. If additional mission time is required, an extended mission duration will be used as opposed to a required revisit flight. (DER)

Dynamic and thermal response tests will be continued during free flight of the platform after the Orbiter has returned to earth. A period of approximately 45 days will be ample to complete the data gathering on the characteristics of the platform. The scientific experiments installed on the flight will be checked out while the platform is still attached to the Orbiter and can be carried out during the free flight portion of the mission on a noninterference basis with the SCAFE experiments.

An optional revisit mission can be performed between two and three months after the first flight for cost-effective use of the platform. Additional scientific and application experiments can be attached and checked out on the platform. These experiments and some of the ones from the first mission can be performed until the orbit decays and the platform enters the atmosphere (providing the orbit altitude is not raised as a result of the revisit mission for longer life and utilization). Figure 3-2 is a graphic presentation of the mission profile. The scientific experiments indicated in the figure are representative of candidate experiments and are not necessarily the recommended ones.

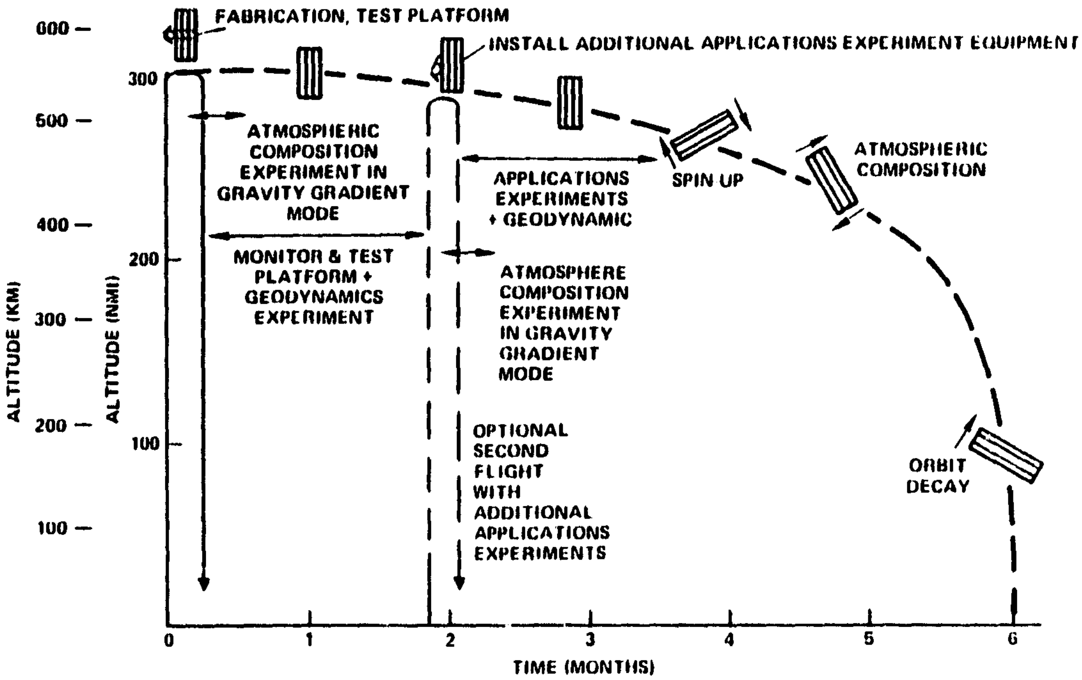

Figure 3-2. SCAFE program mission profile.

Table 3-1 presents a summary of the mission characteristics. The scientific experiments are only representative. Table 3-2 summarizes the flight article elements required for the orbital flight. Requirements for an optional revisit mission will be determined during a future study. Table 3-3 summarizes the on-orbit experiment instrumentation. The scientific experiment equipment is considered GFE and is representative only.

Table 3-1. Baseline mission characteristics.

Mission	Characteristics
Shuttle Flight (Extra payload capacity available)	1
Duration (Max.)	7 days
Launch Date (CY)	10/1/85
Delivery Orbit (Nominal)	28 1/2° Incl. 555 km, Circ.
Mission Objectives	
Fab & Assemble Struct Elements	x
Install Evaluation Instrumentation	x
Determine Platform Response - Dynamic/Thermal	x
Separation	x
Recapture	x
Install Subsystem/Scientific Experiments	x
Conduct Scientific Experiments	(After Orbiter returns to Earth)
Orbiter Support	
Power	Baseline Orbiter
Thermal	Radiator Kit
EVA (Including tools)	Baseline Orbiter
RMS (1 provided in Baseline)	Baseline Orbiter
Structural Interface	Baseline Orbiter
AFD Control & Display	Baseline Orbiter
Crew (CMDR, Pilot, MS-1, PS-1)	4
OMS Kit	1
Guidance & Control	x
Communication Syst.	x
Data Management Syst.	x

Table 3-1. Baseline mission characteristics (Contd).

Experiments (Type)	Characteristics
Structural Response/Deformation	Engineering*
Fabrication & Assembly Techniques	Engineering
Separation/Capture	Engineering
Atmospheric Composition/Density	Scientific
Geodynamics	Scientific
Operations Support	
Flight Operation	
TDRSS	x
POCC (Direction/Monitor)	x
MCC-H (Std. Orb/Msn Control)	x
Ground Operations	
Launch/Landing Site	KSC
Pre-Level IV	JSC
Off Line/On Line	KSC
Post Mission (Equipment)	JSC
Data Processing/Eval/Distribution	TBD

* During the first orbiter flight and the free-flight time before a revisit mission.

Table 3-2. On-orbit structural fabrication equipment and Scientific experiment support subsystems.

Item	Devel. Test	Flight
Beam Builder	DET* DPT**	1
Assembly Jig	DET	
	DPT	1
Platform Structure	TBD	≈ 800 kg (1760 lb) stowed
Spares for Simulated Repair	x	x
Platform Subsystems		x
Communication		
Track Transponder	DET DPT	1
Rendezvous Transponder	↓	1
Data Recorder	↓	1
Antennas	↓	x
RF Downlink (Telemetry Pkg)	↓	1
RF Uplink (Telemetry Rcvr)	↓	1

Table 3-2. On-orbit structural fabrication equipment and scientific experiment support subsystems (Contd).

Item	Devel. Test	Flight
Elect. Pwr/Dist		
Batteries (Secondary)†	DET	x
Solar Panels†	DPT	x
Charge Cntl/Regulators†		x
Interconnecting Wiring		x
Attitude Control†		
Thrusters (Cold Gas), Valves & Plumbing	DET DPT	x
Propellant Tanks		x
Control Electronics		x
Horizon Sensors		x
Magnetic Dampers		x
Grapple Fixture	DET DPT	1
Support Equipment		
Command/Cntl (AFD) (CRT, Keyboard)	TBD	Orbiter Baseline
Bay or Cabin Mounted†		
Sci Exp. Support Structure		x
Subsyst Support Structure		x
Elect I/F Equip		In Basic Equip.
Mech I/F Equip		
Fluid I/F Equip		
Software		Orbiter GPC I/F Exp. Peculiar
Manned Maneuvering Unit	–	2

*DET = Design Eval. Test Article
**DPT = Design Proof (Qual.) Test Article
Scientific Experiment Support - GFE
x=Quantity TBD

Table 3-3. On-orbit experiment instrumentation.

Item	Devel. Test	Flight
Structural Response		
Instrumentation		
Sun Shades	DET	2
Accelerometers	DPT	6
Temperature Probes	↓	x
Retro Reflectors	↓	1000
Laser Beacon and Detector Array	↓	1
TV Camera	↓	1
Controls & Displays (In Orbiter)	↓	x
Laser Retro Reflectors	↓	10
Vibrators	↓	2
Geodynamics		
S-Band Transponder*	DET DPT	2
Atmospheric Composition		
Spectrometer and Radiation* Source	DET DPT	1
Fixed Reflector*	↓	1
Movable Reflectors*	↓	2

*Scientific Experiment - GFE

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3.1.3 OPERATIONAL CONCEPT

3.1.3.1 Ground Operations

a. Scenario. After factory checkout of the completed beam builder, an assembly (SPAH) jig and subsystems, along with the experiment instrumentation, will be delivered to JSC (or other integration site) for Pre-Level IV integration consisting of installation, interface verification, test, and checkout activities. Subsequently, the flight units will be delivered to KSC for integration with Orbiter simulation equipment and with on-line Orbiter equipment. The SCAFE equipment will be installed with the Orbiter in the horizontal position in the Orbiter Processing Facility. The SCAFE equipment will not require special environmental monitoring or control during any ground operations phase, or time-critical prelaunch access at the pad. Payload handling in the vertical position is not planned; however, it is not precluded by the design.

(DER) Post mission inspection of the beam builder and assembly jig will be performed. Any required refurbishment for an optional revisit applications flight for the assembly jig and the beam builder if required will be performed at JSC.

b. Requirements/Constraints.

(JSC 07700) 1. Installation and interface verification of the SCAFE equipment in the Orbiter shall be accomplished in no longer than 14.5 hours.

(SPAH) 2. Experiments should minimize operation on the ground, except to verify interfaces with the Orbiter or to satisfy launch site safety and compatibility requirements.

(SPAH) 3. Experiment-to-Orbiter compatibility testing should be planned to address only unique requirements.

(SPAH) 4. Launch site ground checkout requirements for the SCAFE should be included in design and test of experiment software and checkout procedures.

(SPAH) 5. The experiment shall be designed to require no physical access on the launch pad unless it is absolutely necessary to achieve experiment objectives.

(JSC-07700) 6. The experiment shall be designed to require physical access not earlier than 20 hours after landing, unless required to achieve experiment objectives.

(JSC-07700) 7. Removal of the SCAFE equipment from the Orbiter shall be accomplished in no longer than 3 hours.

3.1.3.2 Mission Operations

(DER) a. Scenario. During ascent (or reentry) to the delivery and operating orbit, the SCAFE equipment is inactive - requiring only mechanical support from the Orbiter. During the assembly operations (Figure 3-3) or subsystem installation and checkout operations, direction/monitor (i.e., top level approval) is provided by ground controllers at the POCC, which is co-located with MCC-H. MCC-H provides Orbiter and overall mission control. Remote experiment direction/control sites are not required. TDRSS is operational and provides adequate communications coverage for the 7-day mission. During the platform free-flight period (before an optional revisit mission), periodic monitoring is required for instrumentation left on board the flight article for long term structural, and attitude behavior measurements.

Post mission data reduction/evaluation/distribution is TBD.

b. Experiments. On-orbit mission operations shall consist of the performance of three experiment phases as follows:

(SOW 4.1.3) 1. Construction Test (Flight 1)

(a) Objective: Demonstrate techniques which are applicable to future automated construction of large structural platforms in space.

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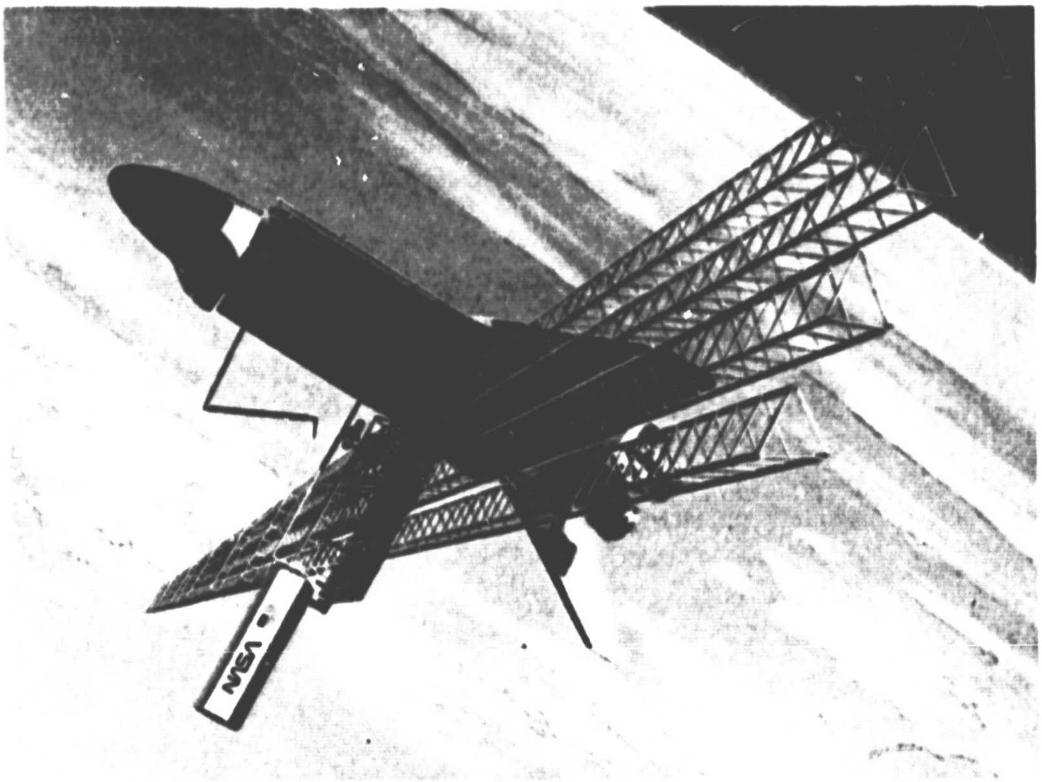


Figure 3-3. Baseline system concept.

(b) Approach: Construct structural platform using beam builder and assembly jig. Orbiter crew will be used for operation checkout and simulated or actual unscheduled maintenance and repair.

2. Engineering Evaluation Tests (SOW 3.0)

(a) Objective: Compare response of large, flexible structure with math model predictions.

(b) Approach: Apply known mechanical and thermal stimuli to structure and observe resulting responses.

3. Scientific Experiments (Representative only). Two types of tests are under consideration which would be conducted using the experiment equipment installed during SCAFE flight, as follows: (SOW 3.0)

(a) Geodynamics

(1) Objective: Map anomalies in earth gravity field to obtain data on internal mass distribution of earth.

(2) Approach: Use doppler frequency shift of satellite-to-satellite and satellite-to-ground links to detect accelerations caused by lateral variations in the gravity field over density anomalies.

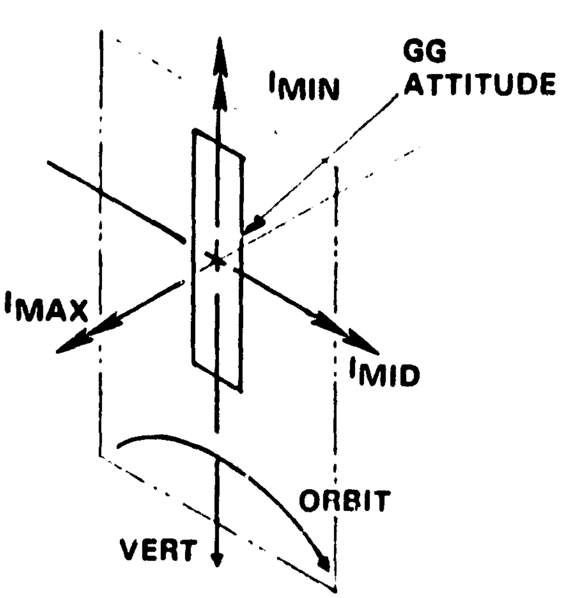
(b) Atmospheric Composition

(1) Objective: Measure composition and density of atmosphere at orbit altitude. (Note: This experiment can also obtain data on dissipation rate of propellant cloud and contamination in vicinity of Orbiter, and can obtain composition and density variation with altitude by continuing measurements as orbit decays.)

(2) Approach: Project radiation over several long, known paths; measure absorption by spectrometer to determine composition and density.

Place radiation source and spectrometer at one end of platform, obtain different path lengths with movable mirrors at various locations on platform (maximum path ~400m down and back on 200m platform). Rotate platform near end of orbit life time and after any revisit missions, with an angular velocity of about 1/15 RPM during data runs to determine effect of orientation relative to flight path. For stability, rotate about axis of maximum moment of inertia with this axis perpendicular to orbit plane.

(DER) 4. Experiment Equipment/Integration. Engineering experiment equipment for the deformation experiments conducted during or after Flight 1 is provided and integrated by the SCAFE contractor. Scientific experiments will be GFP. Subsystem design/integration is provided by contractor as are possibly program developed subsystem provisions such as power distribution, attitude control, stationkeeping, etc.



(DER) c. Requirements/ Constraints

1. The primary control station for experiment operation should be in the aft flight deck. The need for experiment-peculiar control equipment shall be minimized.

2. The experiment shall require activation on orbit not earlier than TBD minutes after liftoff.

3. Experiment design shall allow deactivation TBD hours before touchdown.

4. The experiment should provide the capability to allow easy verification of equipment status and experiment activity to the operator.

3.1.4 ORGANIZATIONAL AND MANAGEMENT RELATIONSHIPS. (TBD)

3.1.5 SYSTEMS ENGINEERING REQUIREMENTS. The following form the basis for SCAFE systems engineering analysis. (DER)

3.1.5.1 Work Breakdown Structure. See Figure 3-4.

3.1.5.2 Specification Tree. See Figure 3-5.

3.1.5.3 SCAFE Functional Flow Diagram. See Figure 3-6.

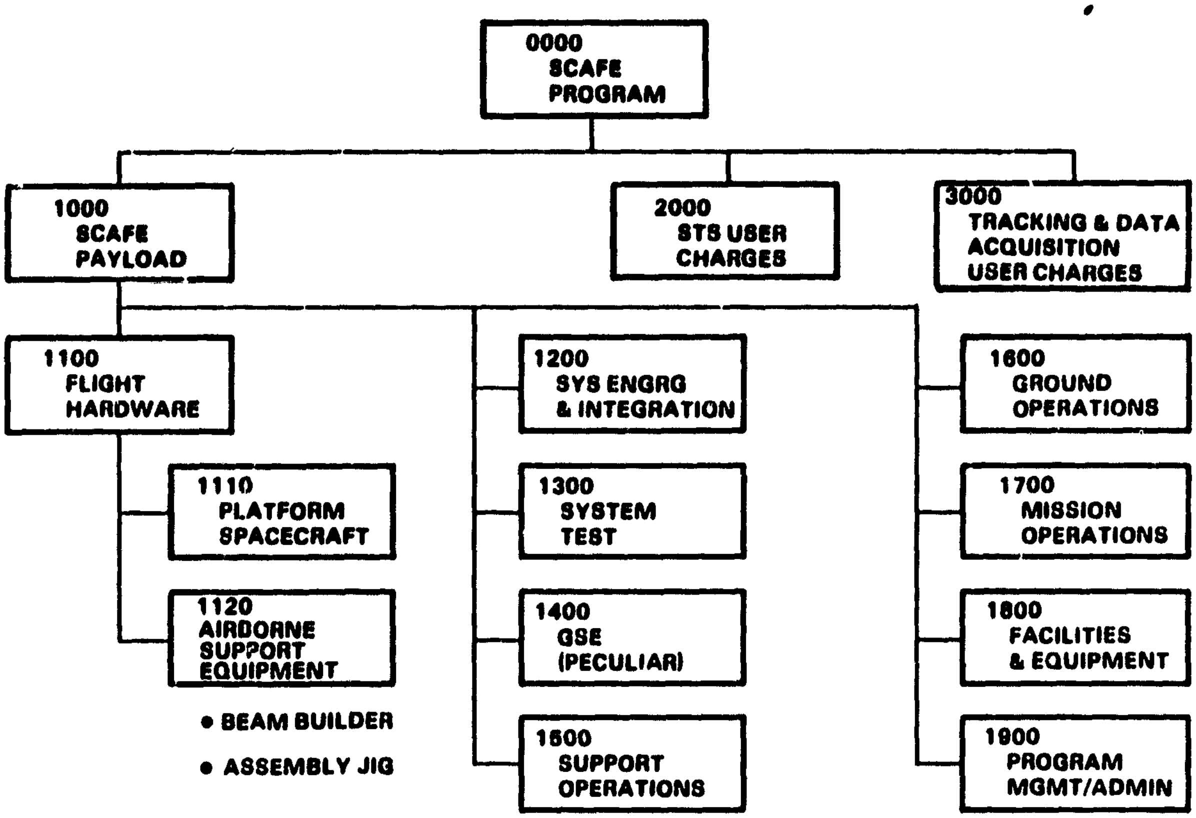


Figure 3-4. SCAFE program work breakdown structure.

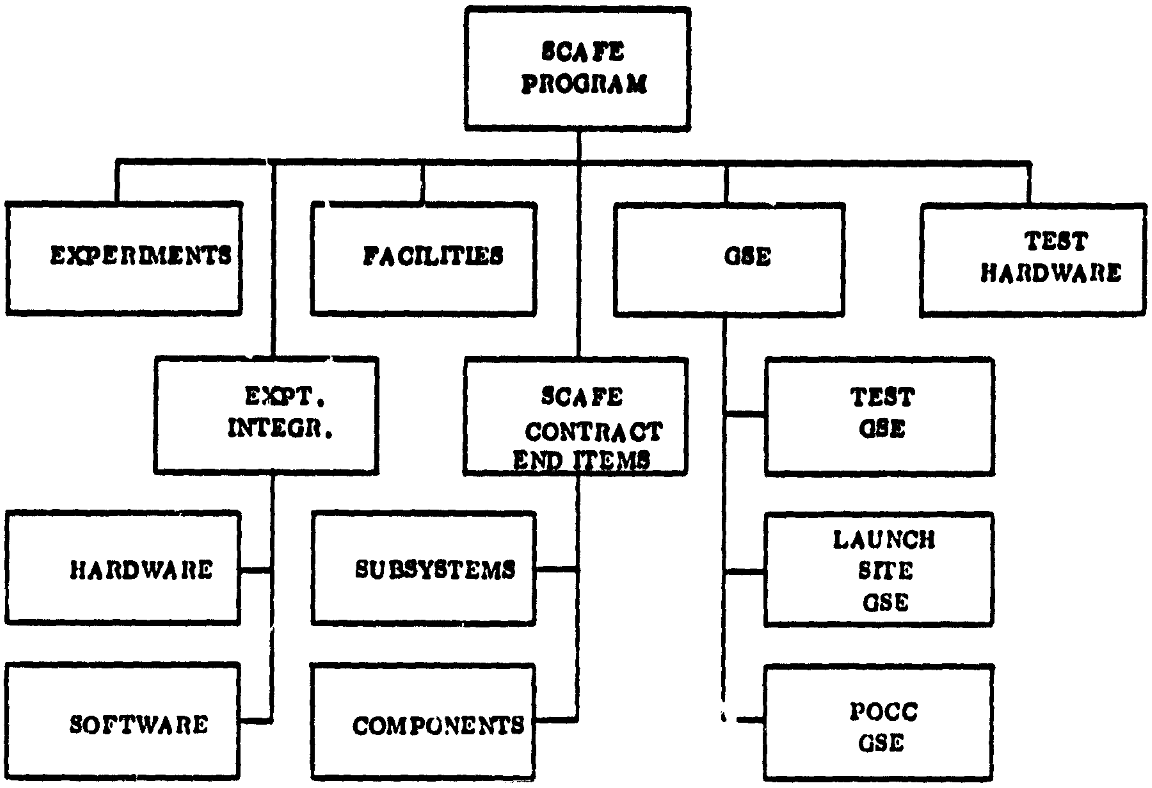


Figure 3-5. Specification tree.

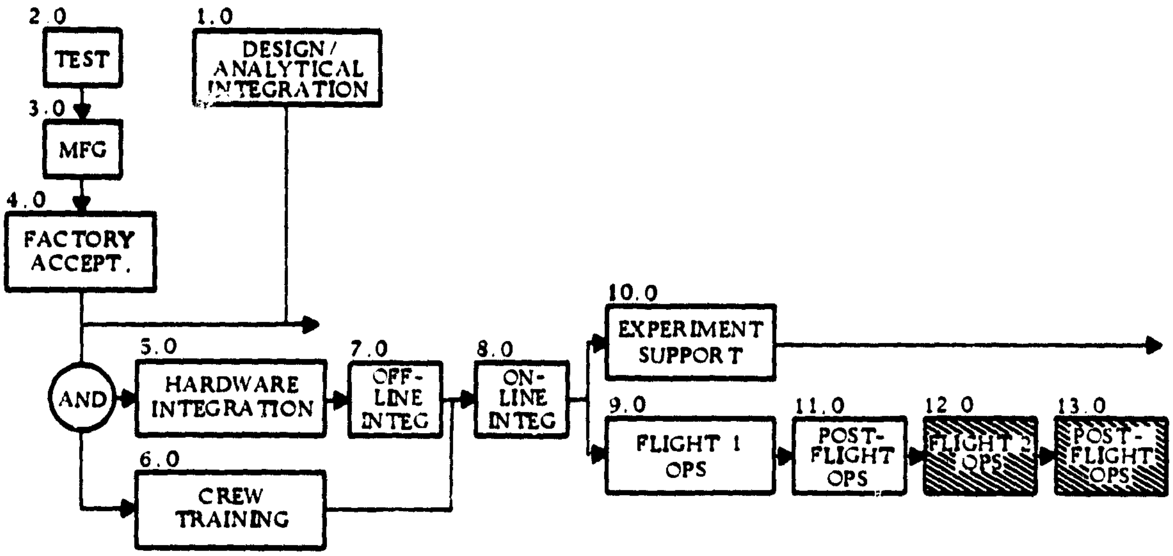


Figure 3-6. Top-level functional flow diagram.

3.1.6 GOVERNMENT FURNISHED PROPERTY. The sensors and supporting equipment (DER) required for the scientific experiments under consideration shall be provided to the SCAFE program as government-furnished property (GFP). The equipment required to conduct the scientific experiments is listed in Table 3-4.

Table 3-4. Scientific experiment summary.

	Weight, kg
Geodynamics	
S-Band Transponders (2)	60
Atmospheric Composition*	
Spectrometer & Radiation Source (Laser)	100
Fixed Reflector	5
Movable Reflectors (2)	30

*Rotational stability and requirements for the atmospheric composition experiment include cold gas expulsion components and consumables (2 kg).

3.1.7 CRITICAL COMPONENTS. Engineering and logistics critical components shall (DER) be listed in the contract end item (CEI) specifications. Selection shall be made on the basis of Failure Modes Effect and Criticality Analysis (FMECA), their development status, usage in the subsystem, and similar considerations.

3.1.7.1 Criticality Categories. Each failure mode shall be identified with a criticality ranking in accordance with the following:

Criticality Category	Definition of Failure Result
Category 1 -	Hardware, failure of which results in loss of life of any crew member. This includes normally passive systems, e.g., emergency detection system, launch escape system.
Category 2 -	Hardware, failure of which results in abort of mission but does not cause loss of life.
Category 3 -	Hardware, failure of which will not result in abort of mission nor cause loss of life.

3.1.7.2 Critical Item List. Critical items shall be listed as follows:

a. Single Failure Points. These are single items of hardware, failure of which will lead directly to a condition described by categories 1 and 2.

b. Critical Redundant/Backup Hardware. This is redundant hardware for which the next failure results in a condition described by categories 1 and 2. This list shall include hardware of operational backup systems.

(SOW 4.1) 3.2 CHARACTERISTICS

The following design guidelines shall be observed:

a. The initial design concept for the space construction experiment shall be as defined in Figures 3-1 and 3-3.

b. Primary emphasis shall be on graphite composite materials for truss materials.

c. The basic truss cross section shall be triangular with continuous caps.

d. The basic truss size shall not be less than one meter deep.

e. Truss fabrication shall be accomplished with automatic construction equipment (beam builder) in orbit from preprocessed stock material. The objective of preprocessed stock material is to complete as much as possible of the truss fabrication process on the ground while retaining a dense package of material for launch.

f. Truss fabrication shall be a continuous process with appropriate lengths cut off (minimizing debris) to use as construction elements.

g. Handling of individual trusses shall be reduced by orienting the beam builder to produce the truss "in situ".

h. EVA capability of the crew shall be used to perform assembly operations that would be difficult or costly to automate.

i. The concept for the beam builder shall be compatible with scale-up to a larger machine for fabrication of the larger (approximately 10-meter) trusses necessary for the future large space platforms.

3.2.1 PERFORMANCE

(SOW 2.0) 3.2.1.1 Flight Functions. The SCAFE system shall provide the capability to fabricate, assemble, and evaluate a large, lightweight structural platform in orbit using the Space Shuttle as a launch vehicle and construction base.

a. Ascent

(DER) 1. SCAFE equipment shall be inactive during ascent requiring only mechanical support and caution and warning support from the Orbiter.

2. SCAFE equipment shall provide equipment stowage locks.

(DER) b. Orbital Altitude and Inclination. The orbital altitude for the SCAFE mission shall be 555 km and the inclination 28.5 degrees.

(DER) c. Fabrication Orientation. Figure 3-7 depicts the SCAFE fabrication orientation, which takes into account mass properties, stability and control, viewing/illumination, thermal control, and communication (Orbiter-TDRSS link).

d. Activation and Checkout. Provisions shall be made for activation and checkout of SCAFE equipment to determine satisfactory performance prior to fabrication/assembly operations, tests, and platform separation. (DER

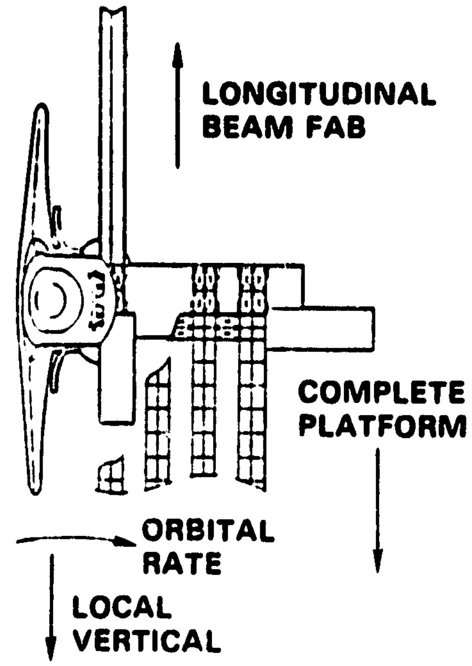


Figure 3-7. Reference fabrication orientation.

e. Deployment.

1. Provisions shall be made for deployment of the SCAFE equipment from the stored position in the Orbiter bay to the operating position.

2. Provisions for power, data, command/control, and thermal resources shall be made for equipment in the deployed position.

f. Truss Fabrication. The trusses shall be automatically fabricated from preprocessed stock material by a beam building machine. The primary members of the trusses shall be fabricated from graphite composite materials. (SOW 3.0,4.

g. Platform Assembly. The trusses shall be held in position by the assembly jig while the attachments between longitudinal beams and cross beams are completed automatically. (DER

h. Attached Engineering Evaluation/Operations. (DER

1. Provisions shall be made to evaluate platform distortion and dynamic response.

2. SCAFE equipment shall be compatible with natural or induced loads occurring during all phases of attached operation.

3. Provisions shall be made for the installation of engineering instrumentation.

4. Provisions shall be made for activation and checkout of installed engineering instrumentation while attached to the Orbiter.

i. Subsystem Installation/Checkout. (DER

1. Provisions for subsystem installation, wiring, etc., shall be made on the platform structure.

2. Provisions shall be made for activation and checkout of installed subsystems while attached to the Orbiter.

(DER) j. Scientific Experiment Installation/Checkout.

1. Provisions for the installation of scientific experiment equipment shall be made.

2. Provisions shall be made for activation and checkout of installed scientific equipment while attached to the Orbiter.

(DER) k. Separation. Provisions shall be made to grapple the platform with the Orbiter RMS and separate the platform from the manipulator arm.

(JSC 07700, Para 8.1.1.2) 1. Residual rates between the Orbiter and platform in all axes shall not exceed the following:

(a) Angular Rate TBD

(b) Linear Motion TBD

(TBD) 2. Placement accuracy for the platform at separation shall be:

(a) Velocity TBD m/sec (radial, tangential, normal)

(b) Position TBD km (radial, tangential, normal)

(Prop. 1.4.2.3) 3. Platform orientation at separation shall be with Y axis aligned with the local vertical.

(Prop. & JSC 07700, Section 8) l. Platform Retrieval. Provisions shall be made to recapture the platform with the RMS during the flight and reattach it to the assembly jig in a manner that it can be translated back and forth by the jig. Platform dynamics prior to retrieval shall be compatible with the payload retrieval requirements specified in Paragraph 3.6.1.1.b.3. The platform may use active or passive means to achieve the required stabilization conditions.

(DER) m. Free-Flying Mode.

1. Provisions shall be made to evaluate platform engineering characteristics and scientific experiments while in the free-flying mode.

(Prop. 1.4.2.3) 2. Attitude control shall be provided by gravity gradient orientation, using a passive damper, if required.

(DER) n. Descent. Functional requirements for descent shall be in accordance with the ascent requirements in paragraph 3.2.1.1.a.

(SOW 1.0) 3.2.1.2 Platform Scale-Up. The techniques, processes, and equipment that are developed for the fabrication and assembly of this test platform shall provide the technology base to be applied for the production of operational large structures that are fabricated in space. Typical applications that will drive detailed design requirements are the Solar Power Satellite (SPS), growth versions of the Orbital Service Module (OSM), and the Public Service Platform (PSP).

Typical parameters which must be considered in scaling up the test platform technology base for developing operational systems are:

a. Physical Considerations.

1. Element scaling (e.g., beam length, depth, material thickness)

2. Joints (e.g., provisions for parallel plane joints or single point joining)

3. Geometric accuracy (e.g., bending and twisting deflection limits)

b. Functional Considerations.

1. Operating life. For example, SPS platform life is expected to be at least 30 years (consider degradation of material due to radiation flux, creep, structural fatigue due to external loads and thermal cycling).

2. Loads (e.g., natural and induced)

3. Reliability

c. Operational Considerations.

1. Assembly

2. Subsystems integration

3. Inspection, maintenance, and repair

4. Transportation (i.e., initial and resupply)

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d. Environmental Considerations.

1. Transportation

2. Operation

3.2.1.3 Representative Applications Descriptions.

a. Near Term Applications. An example of a near term application of large space structure technology is the Microwave Transmission Test Article (MTTA). This would be achieved by increasing platform length and/or width to accommodate a solar array area of TBD m^2, installing a microwave antenna of TBD m^2 at one end, and adding power, orientation, and TTC subsystems. (DER

b. Far Term Applications. An example of a far term application is the Solar Power Satellite concept from "Initial Technical, Environmental and Economic Evaluation of Space Solar Power Concepts." The system consists of 112 Solar Power Satellites (SPS) in a geosynchronous orbit spaced 0.5° apart (~360 km distance at synchronous equatorial). The output of each satellite is 10 GW on ground with power delivered at a frequency of 2.45 GHz via 2 microwave links of 5 GW each. The construction period is from 1995 to 2025 with an initial launch rate of 1 per year, growing later to 7 per year. The total system output on the ground is 1120 GW by the year 2025. (JSC 11568

3.2.2 PHYSICAL

(DER) 3.2.2.1 Weight

a. Launch/Landing Configurations. The maximum allowable weight of SCAFE equipment plus all payload chargeable support equipment and consumables shall not exceed TBD kg and, in addition, shall be compatible with the Space Shuttle weight and c.g. location criteria specified in paragraph 3.6.1.2.b.

b. On-Orbit. The weight of the assembled platform structure shall be no greater than TBD kg.

3.2.2.2 Dimensional.

(DER) a. Launch Configuration. The Space Shuttle cargo bay size available for the SCAFE mission is 4.572 m dia. and 18.288 m long, minus the OMS tank kit length, which is presently 2.74 m. These net available cargo bay dimensions (4.572 m dia. by 15.54 m long) must accommodate the SCAFE equipment and support equipment in their launch configuration.

(SOW 3.0) b. On-Orbit Platform. The platform reference configuration (Figure 3-1) shall consist of four longitudinal trusses, approximately 200 m long, joined by nine crossmember trusses approximately 10.5 m long. All trusses shall have a triangular cross section, with a minimum depth of approximately 1 m.

(DER) 3.2.3 RELIABILITY

3.2.3.1 Reliability Goal. The reliability goal for the planned SCAFE mission shall be TBD.

(DER) 3.2.3.2 Redundancy. Failure modes that result in loss of functions affecting crew survival or mission success require redundant means of accomplishing the function. The redundant means shall provide capability for performing critical functions at a reduced level with any credible combination of two component failures.

(DER) 3.2.3.3 Reliability Design. In designing to achieve system reliability, the following priorities shall be considered:

a. Man and Vehicle Safety. The safety of the crew and Orbiter during launch, orbital construction, and return to Earth.

b. Experiment Equipment Performance. SCAFE system elements that are required to be operational for beam fabrication, platform assembly, engineering evaluation experiments, and scientific experiments.

c. In-Orbit Failure Detection and Repair. Ability to detect that a failure has occurred, ability to analyze the nature and cause of a failure, and the capability to effect timely repair.

3.2.4 MAINTAINABILITY. The design of SCAFE flight articles and support equipment shall provide for: (1) equipment accessibility, (2) rapid fault isolation, (3) ease of remove/replace activities, and (4) the maximum possible use of standard tools and test equipment. (DER

3.2.4.1 Access. Ease of access to all SCAFE components or modules that are replaceable in orbit shall be a design goal. These components shall use connectors and fasteners that permit operation by a crewman's gloved hand, a hand-held tool, or an appropriate RMS end effector.

3.2.4.2 Fault Isolation. Sufficient diagnostic test points shall be included in SCAFE equipment design to facilitate checkout and troubleshooting. Diagnostic capability must, as a minimum, account for all on-orbit replaceable components or replacement modules.

3.2.4.3 Maintenance and Repair. The design of SCAFE equipment shall not include the utilization of planned maintenance during platform fabrication and assembly.

3.2.5 OPERATIONAL AVAILABILITY. The first space construction experiment mission shall be planned for the 1985 time period. (SOW 4.1.6

3.2.5.1 Flight Schedule. For program planning purposes the flight schedule shall be assumed as follows: (DER

1st Flight	October 1985
2nd Flight	December 1985

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3.2.5.2 Operational Life (DER

a. The operational life of the platform in the free-flying mode shall be approximately 6 months.

b. The operational life of the experiment equipment and supporting subsystems shall be a minimum of 6 months.

3.2.6 SAFETY. This section reflects the principles and intentions of NASA Headquarters Office of Space Flight Document "Safety Policy and Requirements for Payloads using the Space Transportation System". Additional safety information is contained in JSC 11123 "Space Transportation System Payload Safety Guidelines Handbook", which provides safety recommendations for experiment design and operation. (SPAH, 8.0)

3.2.6.1 Safety Requirements. Safety, as applied to experiments to be flown on Space Shuttle missions, consists of the requirements and measures taken to assure minimum hazard to the Orbiter and Orbiter crew, and to assure retention of the capability for safe recovery of the vehicle and crew. (SPAH, 8.1)

a. Experiments extended outside the Orbiter cargo bay envelope must have a capability for emergency ejection and/or retraction. This capability shall be provided by a dedicated system capable of control from the Orbiter.

b. Experiments must have the capability of being returned to a safe or inert status at the termination of the experiment operations, including emergency shutdown provisions in the case of hazardous conditions.

c. Experiments and experiment materials which are used or stored in the cargo bay shall be subject to the material control requirements given in paragraph 3.3.2.

3.2.6.2 Hazard Reduction. In order to eliminate or control hazards, the following sequence or combination of requirements shall be implemented:

a. Design for Minimum Hazard. The major goal throughout experiment design shall be to ensure inherent safety through the selection of appropriate design features. This shall also include damage control and containment, and the isolation of potential hazards.

b. Safety Devices. Hazards which cannot be eliminated through design selection shall be reduced and made controllable through the use of safety devices as part of the experiment.

c. Warning Devices. Where it is not possible to preclude the existence, or occurrence of a known hazard, devices shall be included in the design for the timely detection of the condition and the generation of an adequate warning signal coupled with automatic or manual contingency procedures designed to ensure that the hazard cannot become uncontrolled. Warning signals and corrective actions shall be displayed and processed either by experiment data processing command equipment, or by the Orbiter Caution and Warning subsystem.

d. Special Procedures. Where it is not possible to reduce the magnitude of an existing or potential hazard by design, or the use of safety and warning devices, special procedures shall be developed to counter hazardous conditions for the enhancement of ground and flight crew safety.

e. Residual Hazards. Hazards which remain after the application of the hazard reduction sequence and control action are residual risks. These shall be identified and the rationale for acceptance provided.

(SPAH, 8.3) 3.2.6.3 Provisions Against Hazards. The following design requirements are directed towards reducing hazards inherent or incidental to experiments at all times during integration, checkout, launch preparation and launch, orbital, landing, and post landing operations, as appropriate:

a. Hazard Indication. Instrumentation shall be adequate to provide timely indication of hazardous out-of-tolerance conditions, and provision made to correct such conditions prior to the condition becoming a hazard to the crew and/or Orbiter.

b. Rapid Evacuation. Experiments requiring the presence of personnel in the Orbiter cargo bay while on the ground shall not preclude rapid evacuation from the cargo bay in the event of an emergency.

c. Hazardous Material Storage. Toxic, corrosive, and/or flammable materials shall be stored and used such that failure of the primary container will not release the material into the cabin atmosphere or cargo bay. Provision shall be made for the safe collection and storage of used or spent materials, considering also their possible chemical or physical interaction.

d. Fluid Release. Hazardous fluids shall not be released into the cargo bay. Hazardous fluid containment shall be designed to remain intact under crash loads with assurance provided that tank integrity will not be violated by other equipment due to impact as a result of crash loads. Release of inert gases into the cargo bay may be permitted under some conditions.

e. Hazardous Material Isolation. Toxic materials and other materials determined by analysis and/or test to be hazardous must be isolated from the crew and cabin system, and suitable measures for neutralization provided in case of hazard.

f. Material Incompatibility. Where hazards can occur due to the presence or contact of mutually incompatible materials, components at electrical differences or of chemically incompatible substances shall be separated to the maximum practical extent.

g. High Temperature Processes. High temperature processes must be carried out in suitable enclosures. Emergency switch-off in the case of cooling interruption or other control failure must be provided.

h. Rotating Machinery. Rotating machinery must be protected by suitable guards. Where machinery is highly stressed, containment for possible failure must be provided.

i. Material Shattering. Material which can shatter shall not be used in the Orbiter unless positive protection is provided to prevent fragments from entering the cabin environment. Photographic and optical equipment which cannot comply with this standard must be protected by suitable covers when not in use.

j. Stored Mechanical Energy. Mechanical devices such as springs, springloaded levers, and torsion bars which are capable of storing energy should be avoided in experiment design. Where stored mechanical energy devices are absolutely necessary, safety features such as locks, protective devices, and warning placards shall be provided.

k. Equipment Movement. Means for the control of movement of equipment which is not easily hand manipulated shall be provided for ground and orbital operations where applicable. Adequate handles, hoisting and ground support equipment attachment hardpoints shall be included in the design.

l. High Voltage. High voltage systems shall be suitably insulated, isolated, and provided with circuit breakers. Provisions for automatic cutoff of high voltage is required when access to high voltage equipment for adjustment, maintenance, or repair is needed.

m. Experiment Grounding. Experiment grounding shall be such as to preclude electrical discharge hazards and shocks.

n. Accidental Switch Actuation. All switches shall be recessed or otherwise protected against accidental actuation.

o. Emergency Switch Off. A rapid means of switching off power under emergency conditions shall be provided.

p. Lightning Strikes. Safety critical experiment equipment shall be designed, or protection provided, to preclude hazards to the ground and flight crews in case of lightning strikes.

q. Pyrotechnics. Explosive devices capable of producing fragments or significant environment overpressure shall not be used. All experiment pyrotechnic devices shall meet the requirements of JSC document number 08060, "Space Shuttle System Pyrotechnic Specification" or MIL-STD-1512, "Electro Explosive Subsystems, Electrically Initiated, Design Requirements and Test Methods".

r. Radiation Sources. Experiments that contain radioactive materials or contain equipment that generates ionizing radiation shall be identified and approval obtained for their use. The initial description shall state source type, strength, quantity, containment/shielding, and chemical/physical form. Review will be implemented by the JSC Safety Office. Major radioactive sources require approval by the Interagency Aerospace Nuclear Safety Review Panel through the NASA coordinator for the panel.

3.2.7 ENVIRONMENT

(JSC 07700, 4.1)

3.2.7.1 Natural Environment. The following natural environmental criteria must be considered in the design of payload equipment. If so desired, the payload may be protected during delivery to the launch and recovery operations by use of appropriate site facilities, so that it is protected from the environment.

a. Atmospheric.

Pressure	
Surface	12.36 to 15.23 psia (85219.2 to 105007.2 N/cm^2)
35,000 Feet (10 668 m)	3.28 psia (22614.8 N/cm^2) minimum
Temperature	
Surface (Sheltered Uncontrolled)	Minus 23°F (-31°C) to 150°F (66°C)
35,000 Feet (10 668 m)	Minus 65°F (-54°C) nominal

1. Fungus. Temperatures above 68°F (20°C) and relative humidities above 75% are conducive to high growth rates of fungi (including mold) and bacteria, and the design should utilize non-fungi nutrient materials.

2. Humidity. For design purposes, 0 to 100 percent relative humidity at the temperature extremes defined herein shall be the consideration. For those requiring detailed definition of the extreme surface humidity, the following is provided in three categories:

   (a) High Temperature/High Vapor Concentration. The following extreme humidity cycle of 24 hours should be considered in design: 3 hours of 99°F (37.2°C) air temperature at 50 percent relative humidity and a vapor concentration of 9.7 gr/ft^3 (22.2 g/m^3); 6 hours of decreasing air temperature to 76°F (24.4°C) with relative humidity increasing to 100 percent (saturation); 8 hours of decreasing air temperature to 70°F (21.1°C), with a release of 1.7 gr of water per cubic foot of air (3.8 grams of water as liquid per cubic meter of air), humidity remaining at 100 percent; and 7 hours of increasing air temperature to 99°F (37.2°C) and a decrease to 50 percent relative humidity.

   A vapor concentration of 2.1 gr/ft^3 (4.8 g/m^3), corresponding to a dew point of 32°F (0.0°C) at an air temperature of 100°F (37.8°C) and a maximum relative humidity of 26 percent at an air temperature of 70°F (21.1°C) remaining 20 hours of each 24 hours for 10 days.

   (b) Low Termperatures/Low Vapor Concentration. A vapor concentration of 0.9 gr/ft^3 (2.1 g/m^3), with an air temperature of 11°F (-11.7°C) and a relative humidity between 98 and 100 percent for a duration of 24 hours.

3. Ozone. Surface: maximum 3 to 6 parts per hundred million (phm); 35,000 feet (10,668 m): maximum 100 phm. Total oxidant concentrations may infrequently reach 60 phm for 1 to 3 hours during a 24-hour period. Levels increase with altitude to maximum value of 1100 phm near 98,000 feet (29,870 m).

4. Salt Spray. Design Model - 1.0 percent by weight salt (NaCl) solution for 30 days.

   NOTE: For those requiring detailed definition, the following data is provided.

   Natural environments conducive to salt spray corrosion of metals or obscuration of optical surfaces at the surface exist at New Orleans, Gulf Transportation, ETR, Space and Missile Test Center, West Coast Transportation, Wallops Island.

Extreme salt spray characteristics follow:

Particle diameter*, microns	0.1 to 20
Fallout rate on fair day, lb per sq ft/day	5×10^{-8}
Fallout rate on rainy day, lb per sq ft/day	1×10^{-6}
Fallout coating rate on fair day, microns/day	4
Fallout coating rate on rainy day, microns/day	100

5. Sand/Dust. (Sheltered Storage and uncontrolled interior vehicle areas). Equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 gram per cubic foot.

b. Space. Space is normally considered to be altitudes greater than 48.6 n.mi., (295,000 ft., 90 km).

1. Pressure. Values are as follows:

Altitude	Max P. (Torr)	Min P. (Torr)
70 n.mi.	1.4×10^{-5}	8×10^{-6}
100 n.mi.	2.2×10^{-6}	4.7×10^{-7}
500 n.mi.	2.2×10^{-9}	4.7×10^{-11}
1200 n.mi.	approx. 1×10^{-11} in either case	

Highest pressure at orbital altitudes would be the maximum pressure at lowest orbital altitude (70 n.mi.) and lowest pressure at orbital altitudes would be the minimum pressure at the highest orbital altitude (1200 n.mi.).

2. Solar Radiation (Thermal)†. Temperature extremes for items exposed to space environments cannot be categorically defined. When determining these extremes analytically, use the following data:

Environmental Parameter	Design Value
Solar Radiation	443.7 Btu/ft^2/hr (1398.76 W/m^2)
Earth Albedo	30 percent
Earth Radiation	77 Btu/ft^2/hr (243 W/m^2)
Space Sink Temperature	0° Rankine

3. Solar Radiation (Nuclear)†. The natural nuclear radiation environment in terrestial space consists of: (1) galactic cosmic radiation, (2) geomagnetically trapped radiation, and (3) solar flare particle events.

*98% of mass occurs with particles greater than 0.8 microns.

†Only applicable if and when the payload doors are open and the equipment is exposed to space.

(a) Galactic Cosmic Radiation (mainly protons).

Composition: 85% protons, 13% alpha particles, 2% heavier nuclei

Energy Range: 10^7 to 10^{19} electron volts; predominant 10^9 to 10^{13}

Flux outside earth's magnetic field: 0.2 to 0.4 particles/cm^2/steradian/sec.

Integrated yearly rate: approx. 1×10^8 protons per cm^2

Integrated yearly dose: approx. 4 to 10 rads

(b) Trapped Radiation (protons, electrons)

Energy: Electrons >0.5 MeV, Protons 34 MeV

Peak Electron Flux: $>10^8$ electrons per cm^2 per sec (omnidirectional)

Peak Electron Flux Altitude: approximately 1000 n.mi. at equator

Peak Proton Flux: 10^4 to 10^5 protons per cm^2 per sec (omnidirectional)

(c) Solar Flare Particle Events.

Composition: Energetic protons and alpha particles

Occurrence: Sporadically and lasting for several days

Particle Event Model (free space): See Section 2.43. of NASA TMX 64627

$$\text{Protons: } N_p(>T) = \begin{cases} 7.25 \times 10^{11}\, T^{-1.2} & 1\,\text{MeV} \leq T \leq 10\,\text{MeV} \\ 3.54 \times 10^{11}\, E^{-P(T)/73} & 10\,\text{MeV} \leq T \leq 30\,\text{MeV} \\ 2.64 \times 10^{11}\, E^{-P(T)/73} & T > 30\,\text{MeV} \end{cases}$$

$$\text{Alphas: } N_d(>T) = \begin{cases} N_p(>T) & T < 30\,\text{MeV} \\ 7.07 \times 10^{12}\, T^{-2.14} & T \geq 30\,\text{MeV} \end{cases}$$

Where $N_p(>T)$, $N_d(>T)$ = protons/cm^2, alphas/cm^2 with energy $>T$

$P(T)$ = particle magnetic rigidity in mV

$$P(T) = \frac{1}{Ze} \{T(T+2mC^2)\}^{1/2}$$

$Ze = 1$ for protons, 2 for alphas
$mC^2 = 938$ MeV for protons, 3728 MeV for alphas

For near-earth orbital altitudes, the above free-space event model must be modified since the earth's magnetic field deflects some of the low-energy particles that would enter the atmosphere at low latitudes to the poles.

4. Meteoroids*. The meteoroid model encompasses particles of cometary origin in the mass range between 1 and 10^{-12} grams for sporadic meteoroids and 1 to 10^{-6} grams for stream meteoroids.

Average Total Environment:

Particle Density	$0.5 g/cm^3$
Particle Velocity	20 km/sec
Flux Mass Models	

(a) For $10^{-6} < m < 10^{0}$ $\log Nt = -14.37 - 1.213 \log m$

(b) For $10^{-12} < m \leq 10^{-6}$ $\log Nt = -14.339 - 1.584 \log m - 0.063 (\log m)^2$

Nt = No. particles/m^2/sec of mass m or greater
m = mass in grams

Defocusing factor for earth and, if applicable, shielding factor are to be applied.

(DER) 3.2.7.2 Induced Environment. The induced environment conditions that will exist during Shuttle prelaunch, flight, and post landing mission phases shall be considered in the design and/or qualification of SCAFE equipment.

The specific environmental conditions are specified in paragraph 3.6.1.3.

(DER) 3.2.7.3 Experiment Induced Environment. Experiment equipment shall be designed such that any experiment induced environments (e.g., outgassing, debris, conducted and radiated electromagnetic energy, torques, reaction forces, etc.) are within acceptable Orbiter limits.

(DER) 3.2.8 TRANSPORTABILITY/TRANSPORTATION

3.2.8.1 To and From Launch/Landing Site

a. Existing transportation systems, including government-owned transporters, shall be used to the maximum extent possible in the transport of program elements.

b. Packaging, handling, and transportation equipment and procedures shall be selected to withstand the environment and loads imposed by all of the applicable modes of transport, including air transport by C5A. (Reference Figure 3-8.)

*Only applicable if and when the payload doors are open and the equipment is exposed to space.

c. Provision shall be made for the monitoring and measurement of ground or air transportation loads that exceed flight loads.

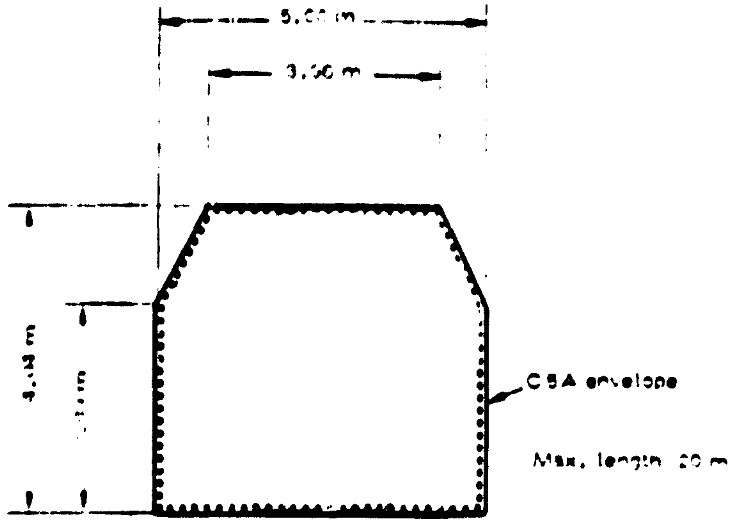

Figure 3-8. C5A cargo envelope for experiment transportation.

3.2.8.2 <u>At Launch/Landing Site.</u> SCAFE equipment shall be designed to be compatible with the launch/landing site cargo support equipment described in paragraph 3.6.1.4.b.

3.2.9 <u>STORAGE</u> (DER)

3.2.9.1 <u>General.</u> Packaging and preservation of SCAFE system elements shall be consistent with the natural environmental conditions of paragraph 3.2.7.1 during storage periods of <u>TBD</u> duration.

3.2.9.2 <u>Shelf Life.</u> Procedures for control of stored items shall be developed to monitor and control items or materials subject to shelf life limitations.

3.3 <u>DESIGN AND CONSTRUCTION STANDARDS</u>

3.3.1 <u>SELECTION OF SPECIFICATIONS AND STANDARDS</u> (DER)

a. All specifications and standards, other than those issued by or approved for use by NASA, must be approved by NASA prior to incorporation into SCAFE specifications.

b. The order of precedence for selection of specifications and standards shall be in accordance with MIL-STD-143B, as follows:

1. JSC Specifications and Standards.
2. Other specifications and Standards of other NASA centers or NASA HQ.
3. Military Specifications and Standards.
4. Federal Specifications and Standards.
5. Contractor-prepared Specifications and Standards.

(SPAH) 3.3.2 GENERAL. This section defines the general design requirements imposed on all SCAFE equipment. The purpose of these requirements is to ensure physical and functional compatibility between SCAFE equipment and the STS during all phases of SCAFE missions and to minimize the risk of damage and/or hazardous conditions which could affect the safety of personnel or equipment.

3.3.2.1 Mechanical Design Requirements.

(SPAH) a. Equipment Mass and Volume. Experiment equipment shall be compatible with the Orbiter mass and volume constraints described in paragraphs 3.6.1.2.b and 3.6.1.2.a, respectively.

(SPAH) b. Equipment Mounting Interfaces. Experiment equipment shall be designed to utilize the standard Orbiter attachment points described in paragraph 3.6.1.2.c.

c. Experiment Integrity.

(SPAH) 1. STS Loads. All experiment equipment shall be designed so that it will withstand the launch and operational dynamic environment defined in paragraph 3.6.1.3 without failures, leaking fluids, or releasing equipment, loose debris, and particles which could damage the Orbiter or cause injury to the crew.

2. Design Factors of Safety. Experiment equipment shall be designed so that the package integrity and load carrying capability of structural mounting provisions have the following minimum factors of safety in lieu of performing static load structural tests:

Yield factor of safety	= 2.0
Ultimate factor of safety	= 3.0

3. Crash Landing. Experiment equipment shall be designed so that, when subjected to the crash landing environment specified in paragraph 3.6.1.3.f, there shall be no hazard to personnel or prevention of egress from a crashed vehicle.

3.3.2.2 Extension, Ejection, Deployment and Retrieval.

(SPAH) a. Emergency Retraction and Ejection. Experiment equipment which may be extended beyond the Orbiter cargo bay envelope shall be designed with a capability for emergency backup retraction and/or ejection. The design of all such emergency capabilities shall allow their initiation from inside the Orbiter. Residual material following emergency retraction or ejection shall not interfere with the closure of the cargo bay doors.

(SPAH) b. Routine Deployment. Equipment which is designed for deployment and/or retrieval using the Orbiter Remote Manipulator System shall comply with the requirements of paragraph 3.6.1.1.b.

3.3.2.3 Crew Interface. (SPAH)

a. General. The requirements of this section apply to the design of all experiment equipment that has a man-machine interface. Where specific requirements are not presented or referenced, the following documents may be used as design guides:

MIL-STD-1472B, MSFC-STD-512A,
JSC-10615

b. Loose Equipment Restraint. Means shall be provided for convenient temporary containment or restraint of all loose experiment equipment that cannot be contained or restrained by Orbiter provisions. This includes items which become loose as a result of disassembly or activation of equipment on orbit. All fasteners, latches, retainers, etc., that are handled by the crew on orbit shall be made captive.

c. Equipment Transfer on Orbit. The following requirements apply to experiment equipment which has to be relocated on orbit. Equipment which has a mass greater than 45 kg shall have a handle or equivalent grasping surface. Equipment which has a mass greater than 95 kg shall have 2 handles or equivalent grasping surfaces. Equipment which is larger than 0.03 m^3 shall have a handle or equivalent grasping surface. Equipment which is larger than 0.2 m^3 or has a mass greater than 110 kg shall have provisions for 2 crew members to handle it.

d. Crew Applied Loads. All experiment equipment that has a potential interface with the crew for operation, use, or impact (whether inadvertent or not) shall be designed to withstand the crew applied loads of Table 3-5 without surface penetration or hazardous failure.

e. Controls and Displays. A minimum set of requirements relating to safety aspects of controls and displays is given here. More comprehensive criteria are contained in MSFC-STD-512A and MIL-STD-1472B.

Switches whose inadvertent activation may cause personnel injury or damage to the Orbiter or whose location may pose a potential source of injury to personnel shall be provided with suitable guards or shall be recessed.

Emergency controls and displays which communicate requirements for immediate action to prevent hazards to personnel or the Orbiter shall be conspicuously located.

Controls shall be located so as to have finger or glove clearance between controls and adjacent hardware.

Table 3-5. Crew-induced limit loads.

Crew System or Structure	Type of Load	Limit Load N (lb)	Direction of Load	Allowable Deflection (mm)
Tether	Concentrated load, pull (tension)	550 (125)	Any direction	N/A
Tether attach point	Concentrated load, pull (tension)	550 (125)	Any direction	N/A
Handholds/Handrails	Concentrated load on most critical 5 cm of member to be grasped	550 (125)	Any direction	13
Foot restraint (each)	Concentrated load, pull	445 (100)	Any possible direction	N/A
	Torsion	200 N m (150 ft/lb)	Torsion vector normal to floor	
Levers, handles, operating wheels	Push or pull concentrated on most extreme tip or edge	200 (45)	Any possible direction	N/A
	Lateral handles force	110 (25)		
Small knobs	Twist (torsion)	15 N m (11 ft/lb)	Any possible direction	N/A
Cabinets, and any normally exposed equipment	Concentrated load-applied by flat round surface with an area of 20 ± 1.5 cm^2	550 (125)	Any direction	N/A

f. Electrical Safety.

1. The crew shall be protected from static electric shock due to static charge buildup in metallic and non-metallic materials of experiment equipment.

2. All experiment electrical connectors, plugs, and receptacles shall be designed to prevent incorrect connection with other accessible connectors, plugs, or receptacles where such connection would result in a hazardous condition.

3. Experiment wire harness installation shall use routing and attachment techniques which would preclude physically mismating connectors where such mismating would result in a hazardous condition.

4. Portable experiment electrical equipment shall have integral power switches.

5. Protective covers or caps shall be placed over electrical plugs and receptacles whenever they are not connected to the mating part. Restraint shall be provided for all protective covers.

g. Thermal.

1. The temperature of any experiment equipment surface which is accessible to the crew inside the Orbiter shall not exceed 45°C.

2. The temperature of any experiment equipment surface which is intended to be accessible to the crew during EVA shall be maintained in the range from -70°C to 93°C.

3.3.2.4 Thermal Requirements. Experiment equipment shall be designed for compatibility with the Orbiter ECS capabilities and interfaces described in paragraph 3.6.1.1.e. (DER)

3.3.2.5 Electrical Power Energy Requirements. Experiment equipment shall be designed for compatibility with the Orbiter power and energy capabilities described in paragraph 3.6.1.1.d. (DER)

3.3.2.6 Command and Data Handling Requirements. Experiment equipment shall be designed for compatibility with the Orbiter CDMS capabilities and characteristics described in paragraph 3.6.1.1.f. (DER)

3.3.2.7 Material Control Requirements. (SPAH)

a. Purpose of Material Control for Experiments. Some requirements must be imposed on specific properties of material and controls exercised on materials being used in experiments to avoid hazards to personnel and detrimental effects on Orbiter equipment. Control must be exercised on the following specific material properties:

   1. Offgassing of possibly toxic or odorous trace contaminants from materials used inside the habitable areas of the Orbiter.

   2. Flammability of materials which can result in fire hazards inside the Orbiter or in the cargo bay.

   3. Outgassing products from materials exposed to vacuum, which may interfere with the correct function of other equipment.

   4. Specific properties of "Forbidden Materials" or "Restricted Materials", which are listed in paragraph 3.3.2.8.f.

b. Orbiter Flight Deck. Materials exposed to the atmosphere of the habitable area of the Orbiter:

   1. Shall not offgass toxic or odorous products at the expected worst case temperatures (Reference NASA NHB 8060.1A, Para. 407 and 406).

   2. Shall be nonflammable in an atmosphere of 23.8% O_2 and 1 atmosphere pressure (Reference NASA NHB 8060.1A, Para. 401).

c. Orbiter Cargo Bay. Material used:

   1. Shall be nonflammable in normal air (Reference NASA NHB 8060.1A, Para 401).

   2. Shall have low outgassing properties in vacuum (i.e., total weight loss $\leqslant$ 1%, and VCM $\leqslant$ 0.1%) (Reference NASA JSC SPR-002).

d. Sealed Containers. The requirements on offgassing, flammability, and outgassing do not apply for materials used inside sealed containers, if such containers do not rupture and emit gases or flames under expected worst case conditions, including internal ignition.

(DER) e. Material Ground Processing Requirements.

1. Cleanliness. The preprocessed graphite/thermoplastic stock shall be maintained at a cleanliness level of TBD during ground processing, storage, and handling.

2. Humidity. The preprocessed graphite/thermoplastic stock shall be maintained at a relative humidity level between TBD % and TBD % during ground processing, storage, and handling.

3. Temperature. The preprocessed graphite/thermoplastic stock shall be maintained at a temperature between TBD and TBD during ground processing, storage, and handling.

(SPAH) f. Forbidden and Restricted Materials.

1. The following materials shall not be used and compliance to this requirement shall be certified:

- Mercury
- Cadmium and cadmium plating
- Zinc
- Polyvinyl chloride (PVC, e.g., wire insulation, wrapping)
- Shatterable or flaking materials, except if suitable protection is provided
- Known carcinogens

2. The use of the following materials shall be restricted as far as possible. If their application cannot be avoided, they may be used only if suitable protection is provided and if formally approved for each individual application by NASA.

- Radioactive materials
- Beryllium and beryllium alloys

3. The use of magnetic materials shall be minimized as far as possible. If their use cannot be avoided, the type, quantity, and location of such materials shall be clearly identified and formally approved by NASA for each individual application. (No formal waiver requests are required for applications which are normal in electronic circuits.)

(DER) 3.3.3 AERONAUTICAL. Aeronautical design and construction specifications and standards shall be used to the extent that they are applicable to SCAFE design and construction.

3.3.4 CIVIL. Not applicable. (DER)

3.3.5 ELECTRICAL (including EMC). Electromagnetic compatibility (EMC) characteristics and measurements shall be in accordance with MIL-STD-461 and MIL-STD-462. (DER)

3.3.6 MECHANICAL. Mechanical design and construction standards are included in the aeronautical specifications and standards of Section 3.3.3. (DER)

3.3.7 NUCLEAR. Not applicable. (DER)

3.3.8 MOISTURE AND FUNGUS RESISTANCE. Moisture and fungus resistance requirements shall be in accordance with the applicable aeronautical specifications and standards of Section 3.3.3. (DER)

3.3.9 CORROSION AND MATERIAL COMPATIBILITY. Materials used in experiment equipment shall be compatible with materials of other equipment with which they come into contact and shall not form corrosion products which could affect the correct function or future use of other equipment. (SPAH, 7.10.7)

3.3.10 CONTAMINATION AND CLEANLINESS REQUIREMENTS. (SPAH, 7.11)

3.3.10.1 General Contamination Control Requirements.

a. Experiment equipment shall be designed to minimize or contain the generation of loose particulate matter and liquid or gaseous contamination which may be detrimental to Orbiter operation or crew safety.

b. Sensitive experiment equipment which needs an operational environment which is cleaner than the environment specified in Section 3.2.7 shall provide the necessary protective covers, purging equipment, etc.

3.3.10.2 Surface Cleanliness.

a. Experiment equipment exterior surfaces shall be free from visible contamination such as scale, particles, rust, dirt, dust, grease, oil, water, and other foreign materials when examined under white light of 540 - 1600 lumens/m^2 and from a distance of 0.3 to 0.6 m.

b. Experiment equipment exterior and accessible interior surfaces shall be designed for easy cleanability.

3.3.10.3 Gaseous Contamination. Experiment equipment shall be designed considering the material control requirements of paragraph 3.3.2.7.

3.3.11 COORDINATE SYSTEM. The coordinate system assigned for SCAFE shall be based upon the Orbiter coordinate system illustrated in Figure 3-9. (JSC) 077000

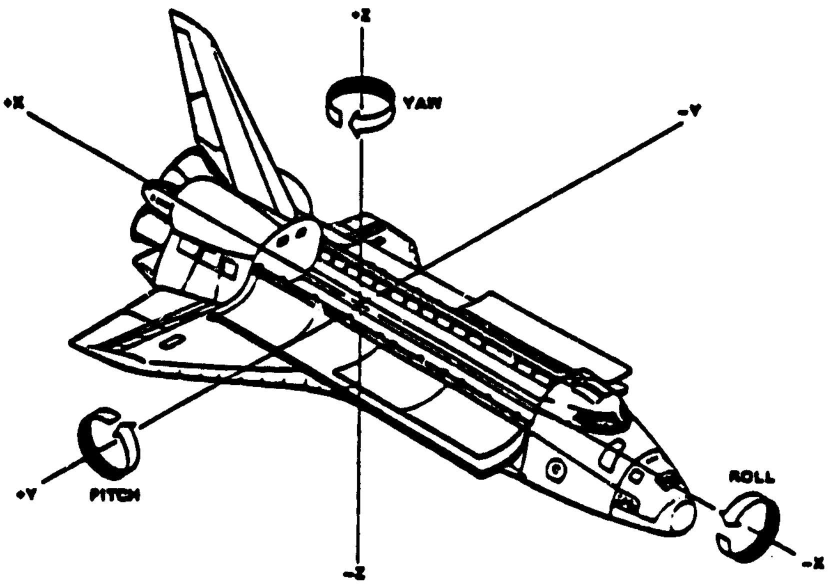

Figure 3-9. Orbiter coordinate system.

(DER) 3.3.12 INTERCHANGEABILITY AND REPLACEABILITY.

a. Replaceable parts, assemblies, subassemblies, and modules having the same part numbers, regardless of source, shall be functionally and dimensionally interchangeable.

b. Accessibility and replaceability shall be achieved in accordance with the requirements specified in Section 3.2.4.

(TBD) 3.3.13 IDENTIFICATION AND MARKING.

(TBD) 3.3.14 WORKMANSHIP.

(TBD) 3.3.15 HUMAN PERFORMANCE/HUMAN ENGINEERING.
(See 3.3.2.3a)

(TBD) 3.3.16 COMPUTER PROGRAMMING.

(TBD) 3.4 LOGISTICS.

(TBD) 3.4.1 MAINTENANCE.

(TBD) 3.4.2 SUPPLY.

(TBD) 3.4.3 FACILITIES AND FACILITY EQUIPMENT.

3.5 PERSONNEL AND TRAINING. (DER

3.5.1 PERSONNEL. Operational personnel shall consist of flight crews and mission support personnel. Flight crews shall consist of a Commander, a Pilot, a Mission Specialist, and a Payload Specialist or; a Commander, a Pilot, and two Mission Specialists. Mission support personnel shall consist of specialists required on the ground at the POCC and remote sites to support experiment operations on Orbit.

3.5.2 TRAINING. (TBD

3.6 INTERFACE REQUIREMENTS.

3.6.1 STS INTERFACES. The functional, physical, environmental, and operational characteristics of the Space Transportation System (STS) with which the SCAFE must interface are presented in this section. (DER

For the purposes of the SCAFE Definition Study, the STS encompasses the Space Shuttle, Launch/Landing Sites and ground processing facilities, and communications networks.

3.6.1.1 Functional. (U.H exce as notec

a. Payload accommodations. The Orbiter systems are designed to support a variety of payloads and payload functions. The payload and mission stations on the flight deck provide space for payload-provided comman and control equipment for payload operations required by the user. Remote control techniques can be managed from the ground when desirable. When used, the Spacelab provides additional command and data management capability plus additional pressurized work area for the payload specialists. The following supporting subsystems are provided for payloads:

- Payload attachments
- Remote manipulator handling system
- Electrical power, fluids, and gas utilities
- Environmental control
- Communications, data handling, and displays
- Guidance and navigation
- Flight kits
- Extravehicular activity (EVA) capability when required

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Payload accommodations are described in detail in the document "Space Shuttle System Payload Accommodations" (JSC 07700, Volume XIV).

All payloads have one or a combination of interfaces with the Orbiter vehicle. The vehicle is designed to provide adequate standard interfaces that can be used by or adapted to most potential payloads. Basic types of interfaces are summarized in Figure 3-10. Additional support systems and flight kits are also available to accommodate payloads.

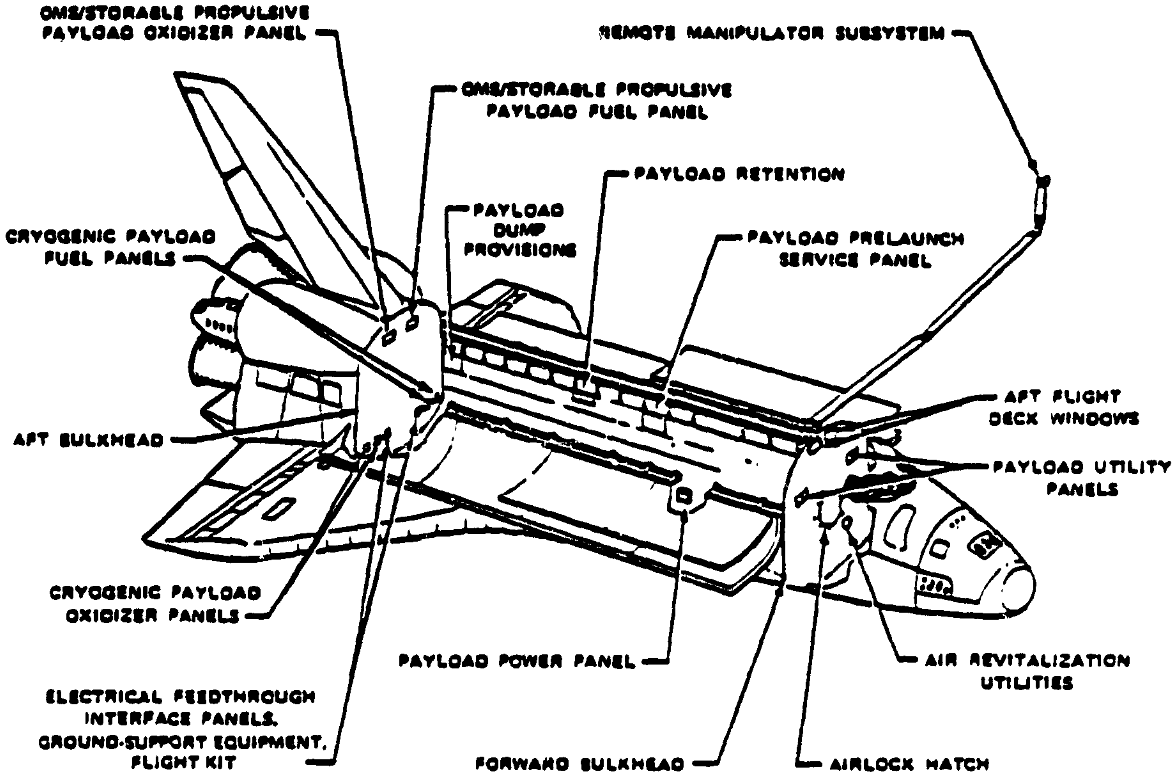

Figure 3-10. Principal Orbiter interfaces with payloads.

b. <u>Deployment and Retrieval.</u>

(U.H.) 1. The deployment and retrieval of payloads will be accomplished by use of the general purpose remote manipulator system (RMS). Deployment can also be accomplished with motor-driven trunnions.

One manipulator arm is standard equipment on the Orbiter and can be mounted on either the left or the right longeron. RMS locations and arm characteristics are shown in Figure 3-11. A second arm can be installed and controlled separately for payloads that require handling with two manipulators. Manipulators cannot be operated simultaneously. However, the capability exists to hold or lock one arm while operating the other. Each arm is associated with remotely controlled television cameras and lights to provide side viewing and depth perception. Lights on booms and side

bulkheads provide sufficient illumination levels for any task that must be performed in the cargo bay. Payload retrieval involves the combined operations of rendezvous, stationkeeping, and manipulator arm control.

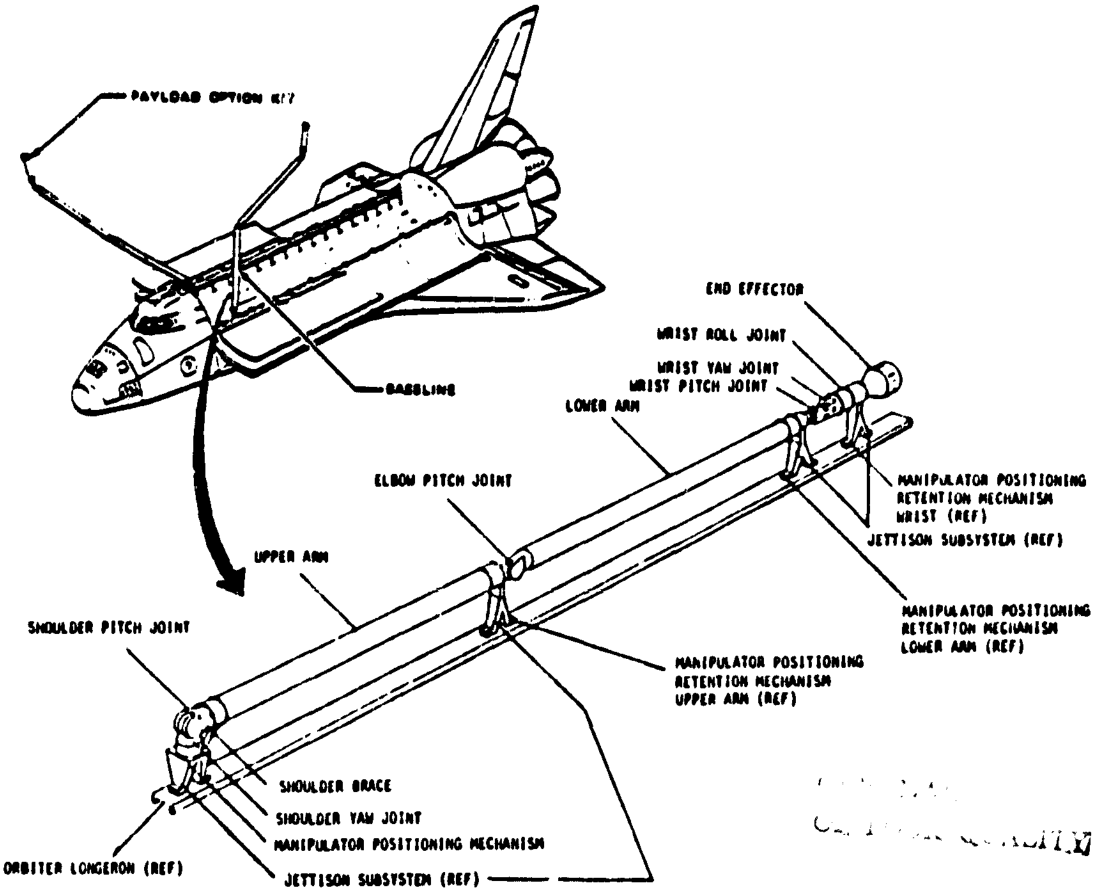

Figure 3-11. Manipulator arm assembly and installation.

2. RMS Performance. Performance capabilities of the RMS are listed in Table 3-6. (JSC 07700, 8.2)

Table 3-6. RMS performance capabilities.

	Torque Range (N-m)		Force (N)		Condition
	Min	Max	Min	Max	
Shoulder Yaw	1047 —	1570	68.68 —	103.20	Straight Arm
Shoulder Pitch	1047 —	1570	68.68 —	103.20	Straight Arm
Elbow Pitch	716 —	1074	81.89 —	121.44	Bent Arm Overall Length < 12.8 m
Wrist Pitch	331 —	470	168.90 —	253.55	Bent Arm Overall Length < 6.09 m
Wrist Yaw	313 —	470	241.76 —	362.97	Bent Arm Overall Length < 4.27 m
Wrist Roll	313 —	470	—		

Note: All values are quotes for the arm under steady state rigid body static condition. E.G. In Payload Bay — And Single Joint Drive.

(JSC 07700, 8.1.1.4.1) 3. Payload Attach Points. For deployment the payload must provide a grapple fixture(s) for the manipulator located within 5% (of payload length) of the Y-Z plane of payload center of mass. Visual aids must be provided to facilitate mating of the payload attach points and the manipulator end effector.

For retrieval the payload must provide a grapple fixture(s) located within 5% (of payload length) of the Y-Z plane of payload center of mass. The payload shall be inertially or local vertically stabilized with maximum limit cycle rates of ±0.1 deg/sec about any axis within a limit cycle which results in ±3 in. (±76 mm) or less motion of the attach point.

(U.H.) c. Cargo Bay Illumination/Surveillance. The locations of cargo bay lights and TV cameras are given in Figure 3-12.

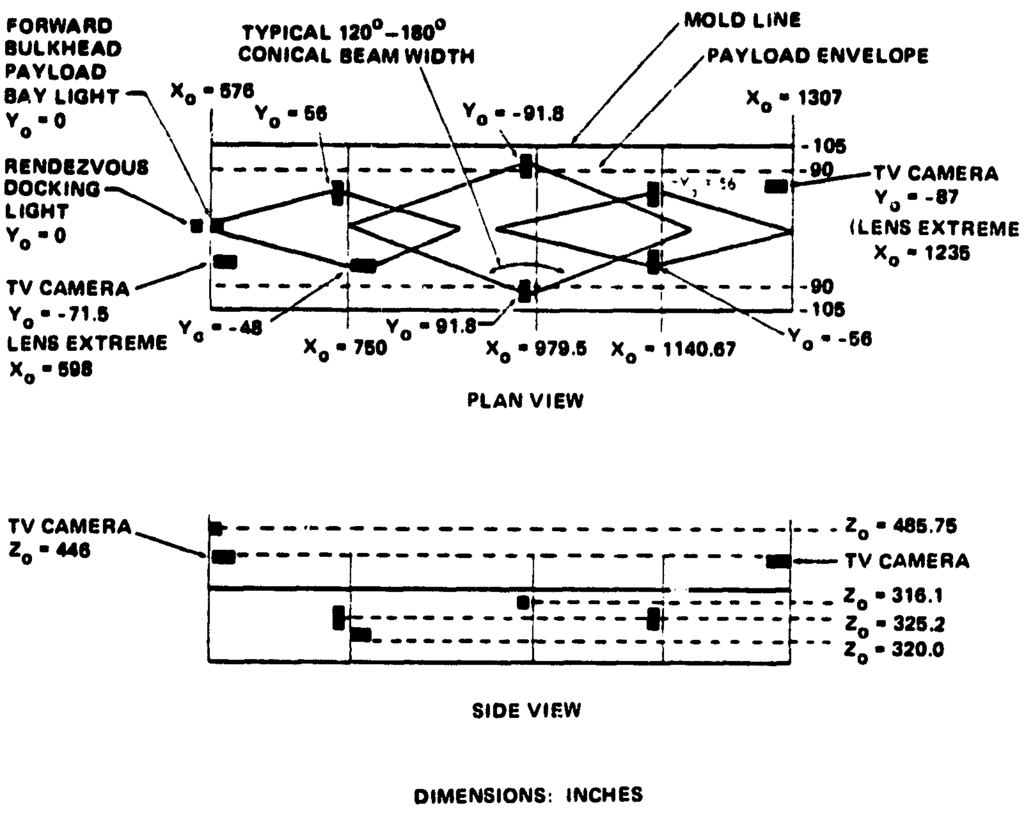

Figure 3-12. Cargo bay light and television camera locations.

d. **Electrical Interfaces.** (U.H.

1. Electrical power is provided to the payload from three fuel cells that use cryogenically stored hydrogen and oxygen reactants. The electrical power requirements of a payload during a flight will vary. During the 10-minute launch-to-orbit and the 30-minute deorbit-to-landing phases (when most of the experiment hardware is on standby or turned off), 1000 watts average to 1500 watts peak are available from the Orbiter. In orbit, as much as 7000 watts average to 12 000 watts peak can be provided to the payload.

   For the usual 7-day flight, 50 kWh (180 megajoules) of electrical energy are available to payloads. If more energy is needed, flight kits can be added as required by the flight plan. Each kit contains enough consumables to provide 840 kWh (3024 megajoules). These are charged to the payload mass and volume.

   Each of three fuel cell powerplants provides 2 kilowatts minimum and 7 kilowatts continuous, with a 12-kilowatt peak of 15 minutes duration every 3 hours.

   Peak voltage can be as large as 39v for power loads less than 2 kW on a dedicated fuel cell.

   Payload power interface characteristics are shown in Table 3-7.

Table 3-7. Payload power interface characteristics.

Flight phase	Interface	X_o station	Voltage range	Power available, kW: Maximum continuous	Power available, kW: Peak	Peak power time limits	Comments
Ground operations (GSE power)	Primary payload bus	645 *	27.2 to 32	1.0	1.5	15 min/3 hr	Normal checkout, limited to 5200 Btu/hr (1523 W)
			27.2 to 32	6	TBD	15 min/3 hr	Orbiter powered down, without radiator kit
			27.2 to 32	7	12	15 min/3 hr	Orbiter powered down, with radiator kit
	Auxiliary payload A	645 * Aft flight deck	26.2 to 32 25.7 to 32	0.4 0.2	25 amp	2 sec	Circuits automatically open when 25 amp is reached; power can be restored by switching off and on
	Auxiliary payload B	645 * Aft flight deck	26.2 to 32 25.7 to 32	0.4 0.2	25 amp	2 sec	
	Aft payload B	1307	28 to 32	1.5	2	2 min/3 hr	Power can be used simultaneously with primary and auxiliary payload buses
	Aft payload C	1307	28 to 32	1.5	2	2 min/3 hr	
	Flight GSE payload panel	1307	TBD	TBD	TBD	TBD	GSE power via T-O umbilical independent of Orbiter
	Cabin payload bus	Aft flight deck	25.7 to 32	0.35	0.42	15 min/3 hr	Normal checkout; total power on aft flight deck (ac or dc) not to exceed 750 W continuous or 1000 W peak
			25.7 to 32	0.75	1	15 min/3 hr	Orbiter powered down
	ac 2 or ac 3	Aft flight deck	115 ± 5 ac	6[illegible]0 VA (3-phase)	1000 VA	2 min/3 hr	Orbiter powered down

*Plus variable length cable.

Table 3-7. Payload power interface characteristics. (Concluded)

Flight phase	Interface	X_o station	Voltage range	Power available, kW: Maximum continuous	Power available, kW: Peak	Peak power time limits	Comments
Prelaunch, ascent, descent, and postlanding	Primary payload bus	645 *	27.2 to 32	1	1.5	2 min/phase	Any active thermal control subsystem configuration
	Auxiliary payload A	645 * Aft flight deck	26.1 to 32 25.7 to 32	0.4 0.2	25 amp	2 sec	Power may be used simultaneously
	Auxiliary payload B	645 * Aft flight deck	26.1 to 32 25.7 to 32	0.4 0.2	25 amp	2 sec	Dedicated fuel cells not available
	Aft payload B	1307	25.7 to 32	1	1.5	2 min/phase	
	Aft payload C	1307	25.7 to 32	1	1.5	2 min/phase	
	Cabin payload bus	Aft flight deck	24.2 to 32	0.35	0.42	2 min/phase	Total power on aft flight deck (ac or dc) not to exceed 350 W continuous or 420 W peak
	ac 2 or ac 3	Aft flight deck	115 ± 5 ac	350 VA	420 VA	2 min/phase	During prelaunch and ascent, ac power not available
On-orbit payload operations	Primary payload bus	645 *	27.2 to 32 27.2 to 32 26.8 to 32	7 6 5	12 TBD 8	15 min/3 hr 15 min/3 hr 15 min/3 hr	With radiator kit; dedicated fuel cell mode; Orbiter powered down Without radiator kit; dedicated fuel cell mode or time-share Orbiter bus with 3 fuel cells operating; Orbiter powered down Load share Orbiter bus with Orbiter loads. 2 or 3 fuel cells operating
	Backup	645 *	28.3 to 32	5	8	15 min/3 hr	Time shared power; one fuel cell failed
	Auxiliary payload A	645 * Aft flight deck	28.5 to 32 25.7 to 32	0.4	25 amp	2 sec	Power can be used simultaneously with all buses
	Auxiliary payload B	645 * Aft flight deck	28.5 to 32 25.7 to 32	0.4	25 amp	2 sec	Total power on aft flight deck (ac or dc) not to exceed 750 W continuous or 1000 W peak
	Aft payload B	1307	24 to 32	1.5	2	15 min/3 hr	
	Aft payload C	1307	24 to 32	1.5	2	15 min/3 hr	
	Cabin payload bus	Aft flight deck	24.2 to 32	0.75	1	15 min/3 hr	
	ac 2 or ac 3	Aft flight deck	115 ± 5 ac	690 VA (3-phase)	1000 VA	2 min/3 hr	

*Plus variable length cable.

(I/F SPEC 3.3.16) 2. Standard connectors are provided at all Orbiter-to-payload interfaces. These connectors do not provide for remote disconnection or reconnection.

e. Environmental Control. Cooling services are provided to payloads by the Orbiter. Prelaunch and postlanding thermal control is provided by ground support systems. In orbit, the primary heat rejection subsystem is the radiators on the inside of the cargo bay doors.

1. Cargo Bay Mounted P/L Equipment. The payload heat exchanger is designed so either water or Freon 21 can be selected as a cooling fluid, according to the needs of the payload. The payload side of the heat exchanger has two

coolant passages; either or both can be used. Each passage is sized for a maximum pressure differential of 6 psi (41 370 N/m^2) with 200 lb/hr (907 kg/hr) of Freon 21, a maximum operating pressure of 200 psia (1379 kN/m^2) and a maximum payload coolant return temperature of 130°F (328 K). Fluid circulation through the payload side of the heat exchanger must be supplied as part of the payload.

The total payload heat rejection provided by the Orbiter is listed in Table 3-8. (U.H.

Table 3-8. Payload heat rejection available.

Flight phases	Capability, kW: Aft flight deck	Capability, kW: Cargo Bay	Description
Prelaunch, ascent, descent, postlanding (cargo bay doors closed)	0.35	1.52	Average
	0.42	N/A	2-min peak
On orbit without radiator kit (cargo bay doors open)	0.75	5.90	Average
	1.00	5.65	Peak for 15 min each 3 hr
	0.35	6.30	Minimum for aft flight deck, Maximum for cargo bay
On orbit with radiator kit (cargo bay doors open)	0.75	8.10	Average
	1.00	7.85	Peak for 15 min each 3 hr
	0.35	8.50	Minimum for aft flight deck, Maximum for cargo bay

2. <u>Air Cooling of Aft Flight Deck.</u> Cooling for payload equipment located on the Orbiter aft flight deck will also be provided by forced air from the Orbiter environmental control system. Standard 38 mm diameter duct connections are provided. The cooling capability will be up to 2560 Btu/hr (0.75 kW) average and 3413 Btu/hr (1.0 kW) peak. Cooling requirements above 1195 Btu/hr (0.35 kW), however, require reduction of the payload cooling provided by the payload heat exchanger. (JSC 07700, 7.1.3

3. <u>Interfaces.</u> Environmental Control System interfaces are identified in Figure 3-13. Orbiter radiator temperature and emissivity are TBD. (TBD

f. <u>Communications, Tracking, and Data Management.</u> (U.H.

1. <u>Voice, Television, and Data-Handling.</u> Voice, television, and data-handling capabilities of the Orbiter support onboard control of the payload or, when desirable, remote control from the ground. The Orbiter communications and tracking subsystem provides links between the Orbiter and the payload. It also transfers payload telemetry, uplink data commands, and voice signals

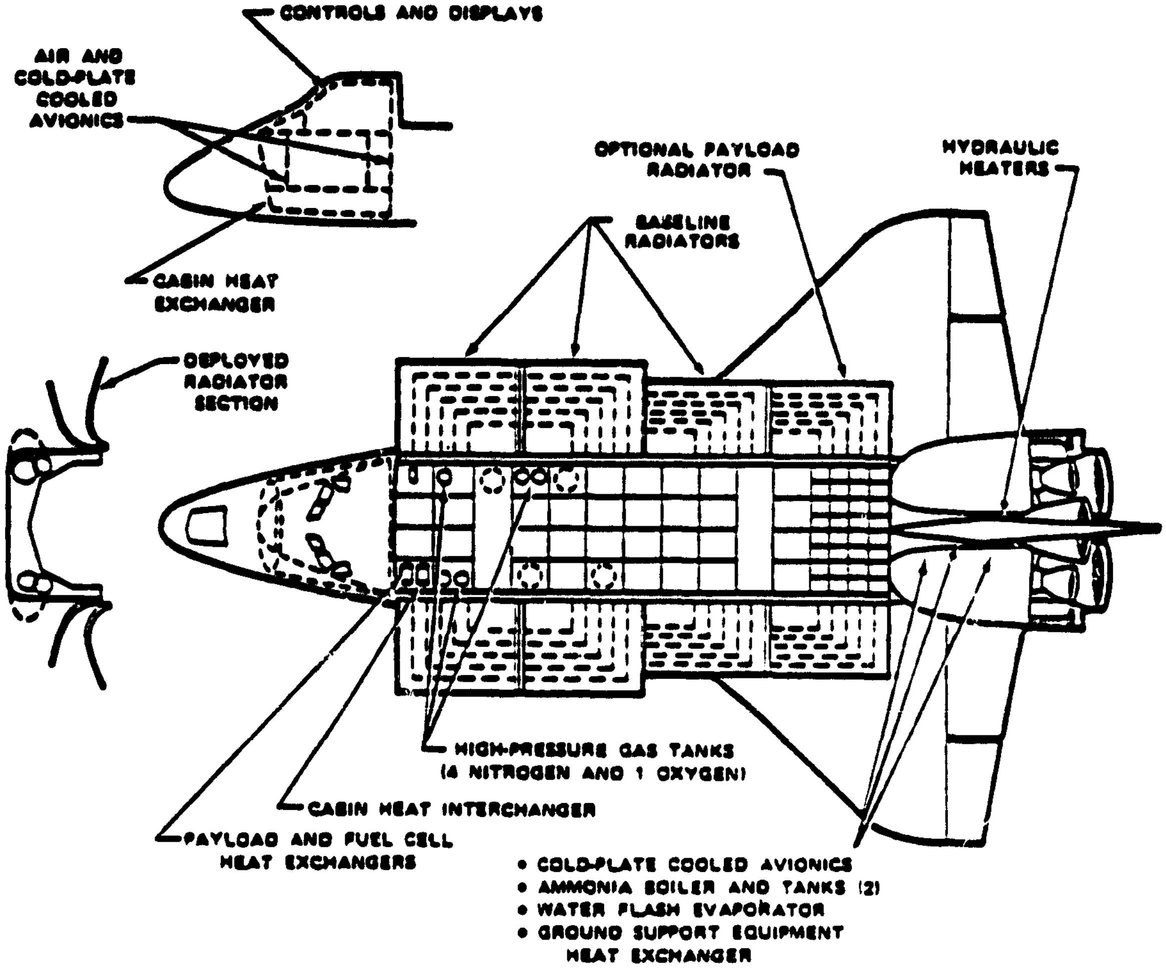

Figure 3-13. Orbiter environmental control subsystem.

to and from the space networks. The provisions in the Orbiter for communications, tracking, and data management are flexible enough to accommodate most payloads. Occasionally, for special missions, some modifications are required.

Links through the Orbiter are outlined in Table 3-9.

The data processing and software subsystem of the Orbiter furnishes the onboard digital computation necessary to support payload management and handling. Functions in the computer are controlled by the mission specialist or a payload specialist through main memory loads from the tape memory. The stations in the Orbiter aft flight deck for payload management and handling are equipped with data displays, CRTs, and keyboards for onboard monitoring and control of payload operations.

Table 3-9. Orbiter avionics services to payloads.

Function	Direct or through Tracking and Data Relay Satellite		Hardline		Radiofrequency link	
	Payload to ground via Orbiter	Ground to Payload via Orbiter	Orbiter to attached payload	Attached payload to Orbiter	Orbiter to detached payload	Detached payload to Orbiter
Scientific data	x	x		x		
Engineering data	x	x		x		x
Voice	x	x	x	x	x	x
Television	x		x	x		
Command		x	x		x	
Guidance, navigation, and control		x	x	x	x	
Caution and warning	x			x		x
Master timing			x			
Rendezvous					x	x

2. Telemetry and data systems. When attached payloads are flown, up to 64 kilobits/sec of data can be displayed to the crew and transmitted (interleaved with the STS operations telemetry) to the ground. The payload data and voice transmission will automatically be recorded on the operations recorder whenever the proper data format and voice channels are selected. In addition, up to 50 megabits/sec of payload data (either in real time or recorded) can be transmitted to the ground via TDRSS. Telemetry and data systems links are shown in Figure 3-14.

3. Communications Network. The network used by the Space Transportation System (Figure 3-15) provides real-time communication links between the user on the ground and his payload — whether it is attached or detached — during most of the time on orbit. This communication, managed either through the Mission Control Center or network control, will originate in the Payload Operations Control Center.

   The communication links provide capability for downlink telemetry data, uplink command data, two-way voice, downlink television, and uplink text and graphics.

   The STS communications network is a combination of the Tracking and Data Relay Satellite System (TDRSS), consisting of two geosynchronous satellites and one ground station, and the space tracking and data network (STDN). The NASA communications network (NASCOM), which may be augmented by an interface with a domestic satellite (Domsat), links the tracking stations with the ground control centers. In addition, the deep space network (DSN) is used to support all interplanetary flights.

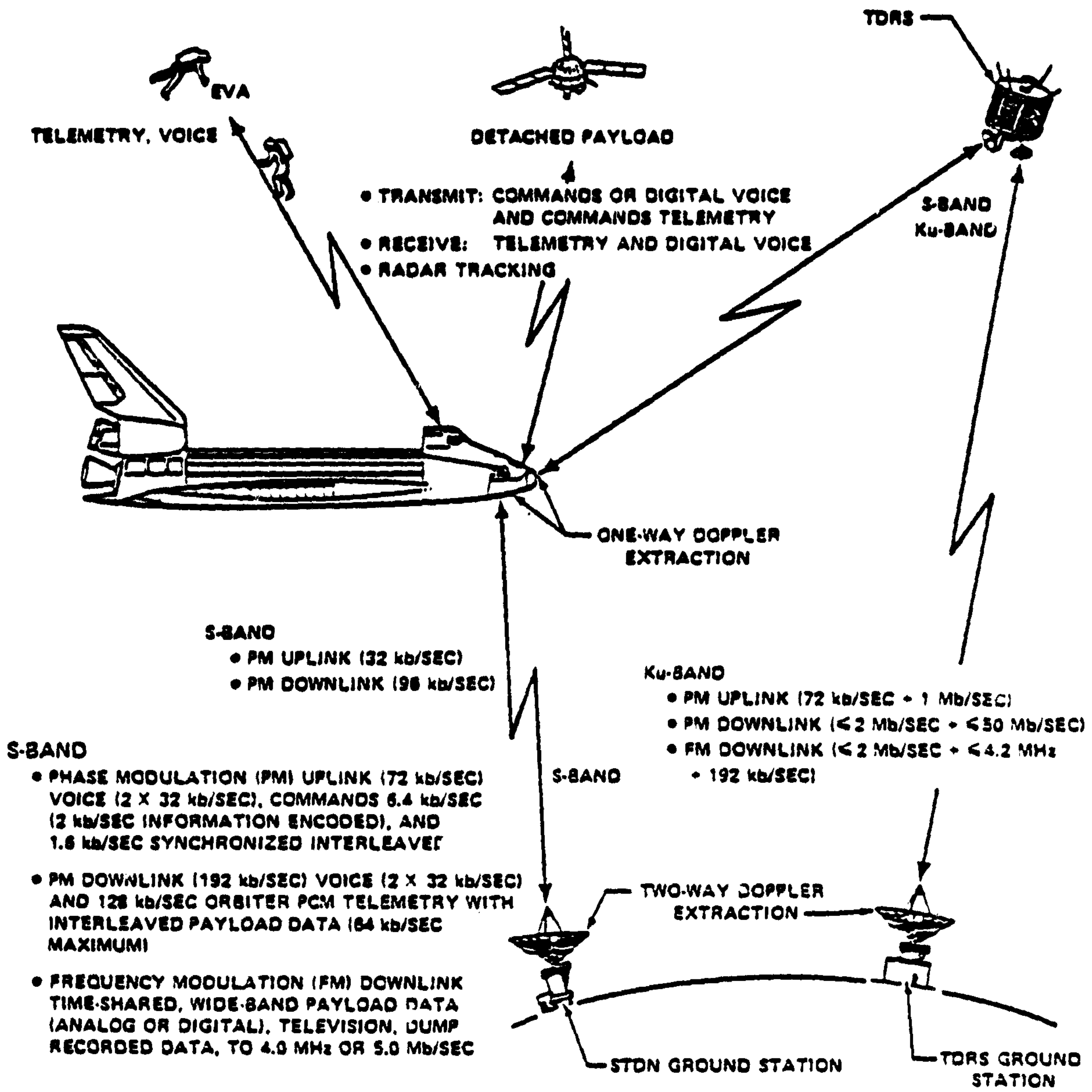

Figure 3-14. Telemetry and data systems links.

4. <u>Tracking and Data Relay Satellite System (TDRSS).</u> The TDRSS provides the principal coverage for all STS flights. It is used to support Orbiter-attached payloads as well as free-flying systems and propulsive upper stages in low and medium Earth orbit. The nearly continuous monitoring capability helps reduce the probability of experiment failure, reduces the need for onboard data storage, and allows for inflight modifications of experiments.

The system consists of two active communications relay satellites in geosynchronous orbits 130° apart as shown in Figure 3-16, and a single ground station at White Sands, New Mexico. The two satellites provide a minimum orbital communications coverage of approximately 85 percent for all space-

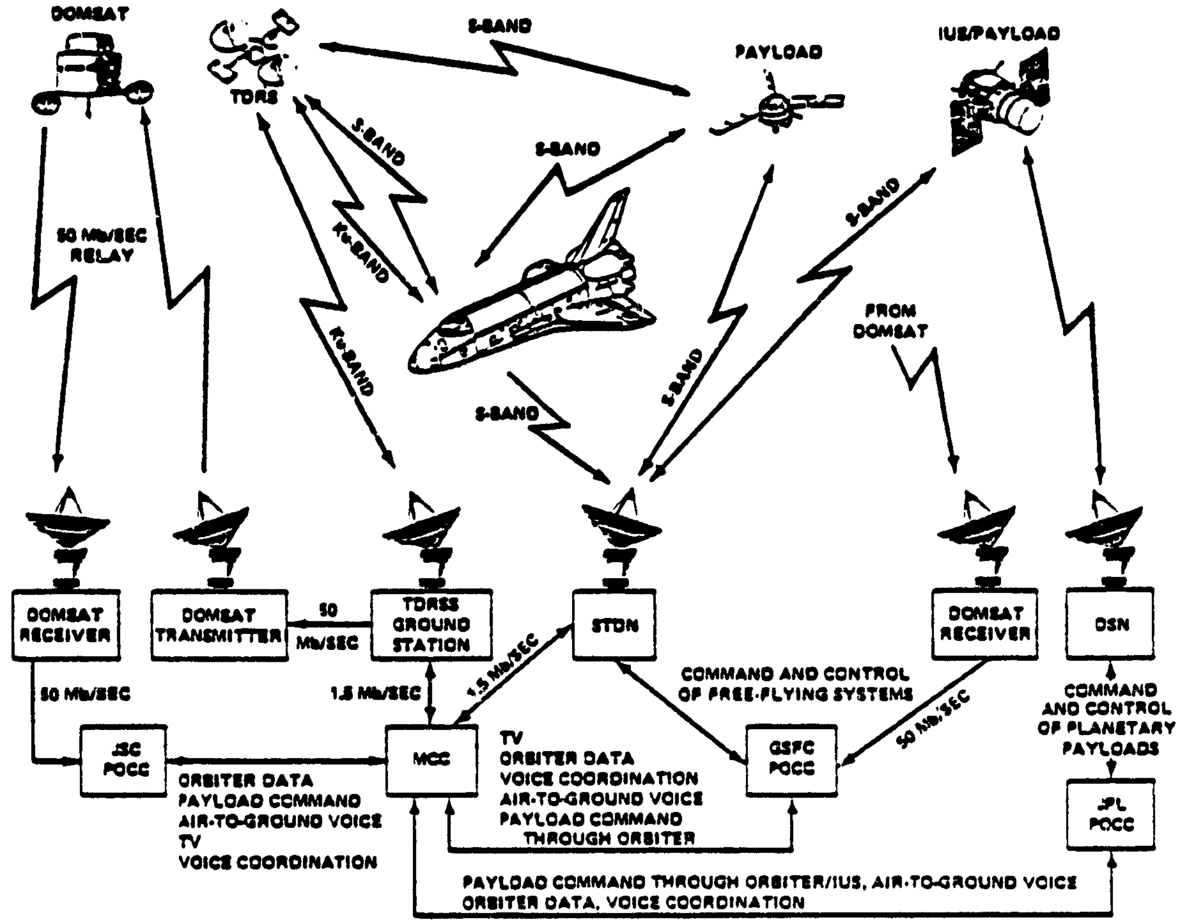

Figure 3-15. Communications network.

craft, even those at the lowest orbital altitude. Coverage increases with altitude as shown in Figure 3-17, becoming approximately 98 percent at 600 nautical miles (1111 kilometers), the highest operating range of the Orbiter. User spacecraft at low altitudes and inclinations will pass through the zone of no coverage during every orbit and, therefore, receive the least coverage. Those at high altitudes and high inclinations will pass through the no-coverage zone only periodically; for example, a spacecraft at 540 nautical miles (1000 kilometers) and 99° will be in the zone only once per day or less. The limited coverage area is generally between 60° and 90° east longitude (central Asia, India, and the Indian Ocean).

Communications coverage by TDRSS may be further constrained as a result of antenna patterns during those payload operations that require specific Orbiter attitudes. For example, an Orbiter "heads down" position for Earth resources viewing could restrict coverage to as low as 30 percent of the time, depending on orbital inclination and Orbiter attitude position.

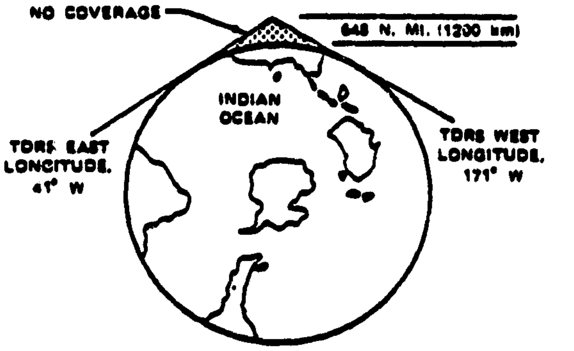

Figure 3-16. Two-satellite Tracking and Data Relay Satellite System.

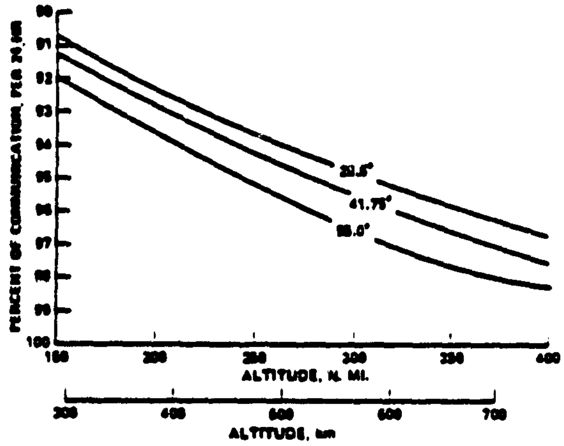

Figure 3-17. TDRSS percent communication variation.

Details of TDRSS capabilities are provided in the TDRSS Users' Guide (GSFC STDN 101.2).

g. Crew.

(U.H.) 1. Duties. The following description of crew duties is summarized from Space Shuttle System Payload Accommodations (JSC-07700, Vol. XIV).

The Orbiter crew consists of the commander and pilot. Additional crew members who may be required to conduct Orbiter and payload operations are a mission specialist and one or more payload specialists. It is assumed that the commander and pilot are always required to operate and manage the Orbiter.

In general, the STS crew members (commander, pilot, and mission specialist) are responsible for operation and management of all STS systems, including payload support systems that are attached either to the Orbiter or to standard payload carriers. The payload specialist is responsible for payload operations, management, and the attainment of payload objectives.

(SPAH) 2. Crew Size. The crew size will be a function of mission complexity and duration, but the maximum crew is TBD persons: commander, pilot, mission specialist, and TBD.

(SPAH) 3. Work Rest Cycle. It is foreseen that for each crew member a sleep cycle of 8 hours is followed by an awake cycle of 16 hours. 8.5 to 10.5 hours of productive work can be expected from each crew member within 16 hours awake time. Crew cycles will be arranged in accordance with mission timelines. Crew cycles are TBD.

h. <u>Extravehicular Activity.</u> Capability for extravehicular activity (EVA) is available on every Space Shuttle flight. Standard equipment and consumables will support two 6-hour, two-person EVAs for payload operations. (Consumables for a third similar EVA must be reserved for contingency operations that might be required for a safe return of the Orbiter and crew.) Additional EVA consumables and equipment can be added as flight kits, which are charged to the payload. (U.H.

All EVA operations will be developed using the capabilities, requirements, definitions, and specifications set forth in Shuttle EVA Description and Design Criteria (JSC 10615).

Standard tools, tethers, restraints, and portable workstations for EVA are part of the Orbiter baseline support equipment inventory. The user is encouraged to make use of standard EVA support hardware whenever possible to minimize crew training, operational requirements, and cost. Any payload-unique tools or equipment must be furnished by the user.

Given adequate restraints, working volume, and compatible man/machine interfaces, the EVA crew members can accomplish almost any task designed for manned operation on the ground.

1. <u>General EVA Guidelines.</u> The following general constraints should be considered in early planning if a payload is expected to require EVA. These limitations are general in nature and, in certain circumstances, variations may be possible. All EVA design requirements are controlled by JSC SC-F-0006.

   (a) EVA operations are normally performed by two EVA-trained crew members; however, one-man EVA is also possible. A second EVA crewman will be on standby during one man EVAs. (U.H.

   (b) Planned EVA periods should not exceed one 6-hour duration per day (excluding the time required for preparation and post-EVA activities); this does not preclude multiple shorter EVA. (U.H.

   (c) EVA may be conducted during both light and dark periods. (U.H.

   (d) EVA will not be constrained to ground communications periods. (U.H.

   (e) An EVA egress path into the cargo bay, 4 feet (1219 millimeters) minimum length, must be available adjacent to the airlock outside hatch; payloads that infringe into this area must be capable of being jettisoned to allow for contingency EVA operations. (U.H.

   (f) The size of the airlock and associated hatches limits the external dimensions of packages that can be transferred to or from payloads to 18 by 18 by 50 inches (457 by 457 by 1270 millimeters). (U.H.

(U.H.) (g) Payloads requiring EVA operations must have access corridors and work areas large enough to allow the EVA crew member to perform the required tasks safely and with adequate mobility - a translation path requiring the EVA crew member to use mobility aids must be at least 43 inches (1092 millimeters) in diameter; additional volume is required when abrupt changes in the direction of travel are required; tasks requiring extensive body and arm manipulation require a working envelope 48 inches (1219 millimeters) in diameter.

(U.H.) (h) EVA is an acceptable mode of operation in low-Earth-orbit radiation zones if flight planning constraints inhibit planning around them.

(JSC 10615) (i) The RMS may be used for EVA crew translation and worksite stabilization (i.e., EVA workstation attached to RMS) when properly equipped with mobility/restraint aids. The RMS end effector must be secured at the worksite prior to translation along the RMS or ingress to an attached work station.

(JSC 10615) (j) Nominal or maximum EVA (i.e., safe) crewman translation rates have not been established for either unencumbered crewmen or crewmen performing cargo transfer functions. Under conditions of a straight handrail translation path through the Orbiter payload bay, it is generally accepted that unencumbered translation rates in excess of 0.6 m/sec (2 fps) can safely be attained. Crewmen transferring cargo may have EVA translation rates of 0.3 to >1.0 fps depending on package weight, volume, transfer path, etc.

(JSC 10615) 2. <u>Hardware EVA Guidelines.</u>

(a) Payloads will provide access to the EVA work area and to the components requiring service.

(b) Payloads should provide attach points for EVA workstations, restraints, tethers, etc., on the payload.

(c) Payload designs will adhere to sharp edges, corner and protrusion criteria JSC10615 along translation paths and at worksites to avoid possible damage to the EMU.

(d) All payload handrails/handholds should be compatible with the Orbiter design.

(e) Payloads will provide crew safety from electrical, fluid, radiation, mechanical, and other hazards.

(f) Payload equipment or surfaces sensitive to inadvertent physical damage by an EVA crewman should be protected or located outside the EVA translation path or EVA work areas.

(g) The payloads should provide crew and equipment restraints or their provisions for attachment at the payload worksites. EVA will not be performed in a free-float condition.

(h) The EVA crewman and equipment should be firmly secured or tethered at all times.

(i) Crew translation tethers or umbilicals should be restrained to preclude damage or entanglement and possible damage to surrounding equipment.

(j) Work areas and crewman interface provisions should be standardized as much as practical to minimize development and training costs. Equipment operation should be designed around conventional, well-known techniques.

(k) Cargo/equipment transfer aids will be available for payload EVA support with the associated weight and volume payload-chargeable.

(l) Portable EVA workstations will be provided for Orbiter and payload application. The workstation may be installed at the worksite prior to or during the EVA.

(m) All equipment transported or handled during EVA should provide a safety tether attach point.

(n) Payloads sensitive to EVA equipment effluent discharge should either provide inherent self-protective features, provide protectors to be installed by the EVA crewman, or define EVA crewman operational constraints.

(o) Universal Skylab-type EVA foot restraints are baselined for Orbiter and payload applications.

(p) As applicable, EVA support equipment design and lighting will adhere to JSC specifications SC-F-0006 and SC-L-0002, respectively.

(q) Crewman translation provisions (e.g., handrails, handholds, mobility aids) in the payload planned EVA work area shall be provided by the payloads if requirements exceed Orbiter attached payload bay handrails.

3. <u>Orbiter EVA Guidelines.</u> (JSC 10615)

(a) Orbiter attitude perturbations will be controlled for compatibility with EVA operations.

(b) Use of Orbiter attitude to satisfy lighting or thermal requirements of EVA will be minimized or limited to contingency operations.

(c) Orbiter thrusters whose plumes could impinge on the EVA crewman, sensitive instruments, or experiments will be inhibited during planned EVA.

(JSC 10615) 4. Mission Requirements. The EVA period of the mission is generally considered as comprised of three phases, EVA preparation, EVA operations, and post-EVA activities.

(a) EVA Preparation. Approximately 1 to 2 hours will be required by 1 or 2 EVA crewmen to complete the preparation activities for an EVA. The activities are preceded by the start of the required three hours of prebreathing, which occurs 3 hours 30 minutes prior to the scheduled start of an EVA. For nearly 2 hours of the 3-hour prebreathe, the EVA crewman may perform required EVA or non-EVA related activities.

The EVA crewmen begin the EVA preparation period by unstowing associated EVA equipment. Special EVA equipment, such as cameras, will then be prepared and checked for the EVA and placed in the airlock. The EMU will be unstowed and the crewmen will don the suits and life support equipment. Ancillary suit equipment, such as the waste management system and the liquid cooling garment, are donned prior to donning the suit.

Approximately 30 minutes prior to the start of the EVA or at the completion of the 3-hour prebreathe period, the crewmen will doff the prebreathe masks and don the helmet and gloves. Following a suit O_2 purge, the crewmen perform a check of the life support equipment and Orbiter/EVA communication systems. Backup communication modes are also checked. The crewmen perform an integrity check of the EMU and begin depressurization of the airlock. After depressurization, the outer airlock hatch is opened for the start of the EVA.

(b) EVA Operations. The EVA tasks are performed outside the Orbiter cabin for a maximum duration of 6.0 hours which is the nominal limit of the life support system consumables.

(c) Post-EVA. When EVA operations are completed, the crewmen ingress into the airlock, close the outer hatch, and repressurize the airlock. Helmets and gloves are doffed along with the EMU. The crewmen then perform a recharge of the life support system. Consumables are replenished and the life support equipment is prepared for the next EVA. Loose equipment and donning aids are stowed and suit drying initiated, if required. About 1.5 hours are required for post-EVA.

(U.H.) 5. Manned Maneuvering Unit. Additional EVA capability is provided by the manned maneuvering unit, a propulsive backpack device (using a low-thrust, dry, cold nitrogen gas propellant) which enables a crew member to reach areas beyond the cargo bay. The unit has a six-degree-of-freedom control authority, an automatic attitude hold capability, and electrical outlets for such ancillary equipment as power tools, a portable light, cameras, and instrument monitoring devices. Because the unit need not be secured to the Orbiter, the crew member can use it to "fly" unencumbered to berthed or

free-flying spacecraft work areas, to transport cargo of moderate size such as might be required for spacecraft servicing on orbit, and to retrieve small, free-flying payloads that may be sensitive to Orbiter thruster perturbation and contamination. (The unit's own propellant causes minimal disturbances with no adverse contamination.)

Figure 3-18 shows the MMU location in cargo bay with airlock/tunnel adapter. Table 3-10 gives the propellant usage versus distance and cargo weight.

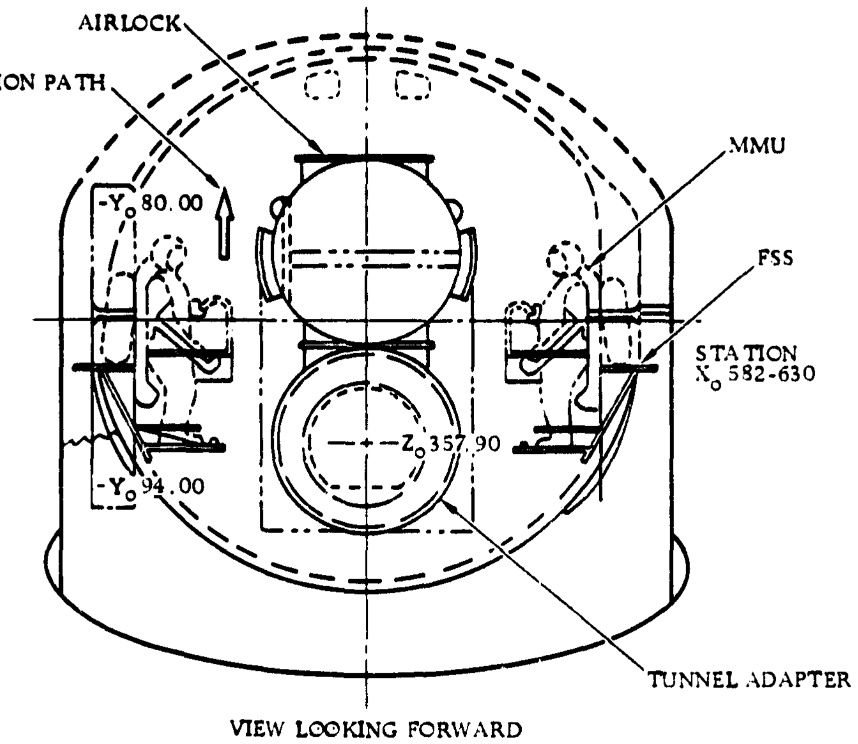

Figure 3-18. MMU locations in cargo bay with airlock/tunnel adapter.

i. Pointing and Stabilization. The Orbiter is capable of attaining and maintaining any specified inertial, celestial, or local (vertical) earth reference attitude. For payload pointing by use of the vernier thrusters, the Orbiter flight control system provides a stability (deadband) of ±0.1 deg/axis and a stability rate (maximum limit cycle rate) of ±0.01 deg/sec/axis. When using the primary thrusters, the Orbiter provides a stability of ±0.1 deg/axis and a stability rate of ±0.1 deg/sec/axis. (U.H.

The Orbiter capability to point a vector defined in its inertial measurement unit (IMU) navigation base axes (using the Orbiter IMU for attitude information) is summarized in Table 3-11. The duration of continuous pointing within a specified accuracy is primarily dependent upon the IMU platform drift.

Table 3-10. MMU travel times (one way) and propellant usage versus distance and cargo weight.

Distance One Way (feet)	Cargo Weight (lb)	v_{max} (fps)	Total Time (sec)	Coast Time (sec)	Percent Fuel Consumed
300	0	5	77	43	7.4
300	0	3 (nominal)	110	90	4.5
300	100	5	79	41	8.6
300	100	3 (nominal)	112	89	5.2
100	0	5	37	3	7.4
100	0	1 (nominal)	103	97	1.5
100	100	5	39	1	8.6
100	100	1 (nominal)	104	96	1.7

NOTES: (1) Translation only, does not include attitude hold propellant usage.
(2) Assumes constant I_{sp}, constant system mass.
(3) Calculated for 95% man, total weight (man/EMU/MMU) = 620 lb (282 kg)
(4) Acceleration $\propto$ system mass.
(5) Propellant mass used = $c\Delta v$, where $c \propto$ system mass.

Table 3-11. Total (half-cone angle) pointing accuracy using Orbiter IMU.

Reference	Half-cone angle pointing accuracy (3 sigma), deg*	Pointing accuracy degradation rate (3 sigma), deg/hr/axis	Duration between IMU alignments, hr
Inertial and local vertical	±0.5	0.105	1.0
Augmented inertial	±0.44	0	N/A
Earth-surface fixed target	±0.5	0.105	0.5

*Mechanical and thermal tolerances may degrade pointing accuracy as much as 2°.

With augmented pointing systems and procedures, however, the pointing duration may be restricted by operational constraints such as thermal or communication considerations. Typical Orbiter RCS maximum acceleration levels during maneuvering and limit cycle pointing control are shown in Table 3-12. These figures are for single-axis (one degree of freedom) maneuvers, based on an Orbiter with 32,000 pounds (14 515 kilograms) of cargo.

Table 3-12. Typical Orbiter RCS maximum acceleration levels.

RCS System	Translational acceleration, ft/sec^2 (m/sec^2)					Rotational acceleration, deg/sec^2			
	Longitudinal		Lateral	Vertical					
	+X	−X	± Y	+ Z	−Z	± Roll	+ Pitch	− Pitch	±Yaw
Primary thruster	0.6 (0.19)	0.5 (0.16)	0.7 (0.22)	1.3 (0.40)	1.1 (0.34)	1.2	1.4	1.5	0.8
Vernier thruster	0 0	0 0	0.007 (0.0021)	0 0	0.008 (0.00[illegible])	0.04	0.03	0.02	0.02

j. Optional Flight Kits. A group of flight kits to provide special or extended services for payloads can be added when required. They are designed to be quickly installed and easily removed. The major flight kits are: (U.H.

- Oxygen and hydrogen for fuel cell usage to generate electrical energy
- Life support for extended missions
- Added propellant tanks for special on-orbit maneuvers
- Airlocks, transfer tunnels, and docking modules
- A second high-gain antenna
- Additional radiator panels for increased heat rejection
- Additional storage tanks

These flight kits are considered part of the payload and, as such, are charged to the payload weight and volume allocation. The most significant payload weight increase results from the additional energy kits. The extra tanks may result in a significant volume penalty as well.

3.6.1.2 Physical Interfaces.

a. Envelope Available to Payload. Payload accommodations are provided in two general areas of the Orbiter: the cargo bay and the aft flight deck in the cabin. (U.H.

The cargo bay dimensions and envelope of the bay are illustrated in Figure 3-19, along with the structural and payload coordinate systems. The Orbiter stations (in inches with millimeters in parentheses) are included for reference.

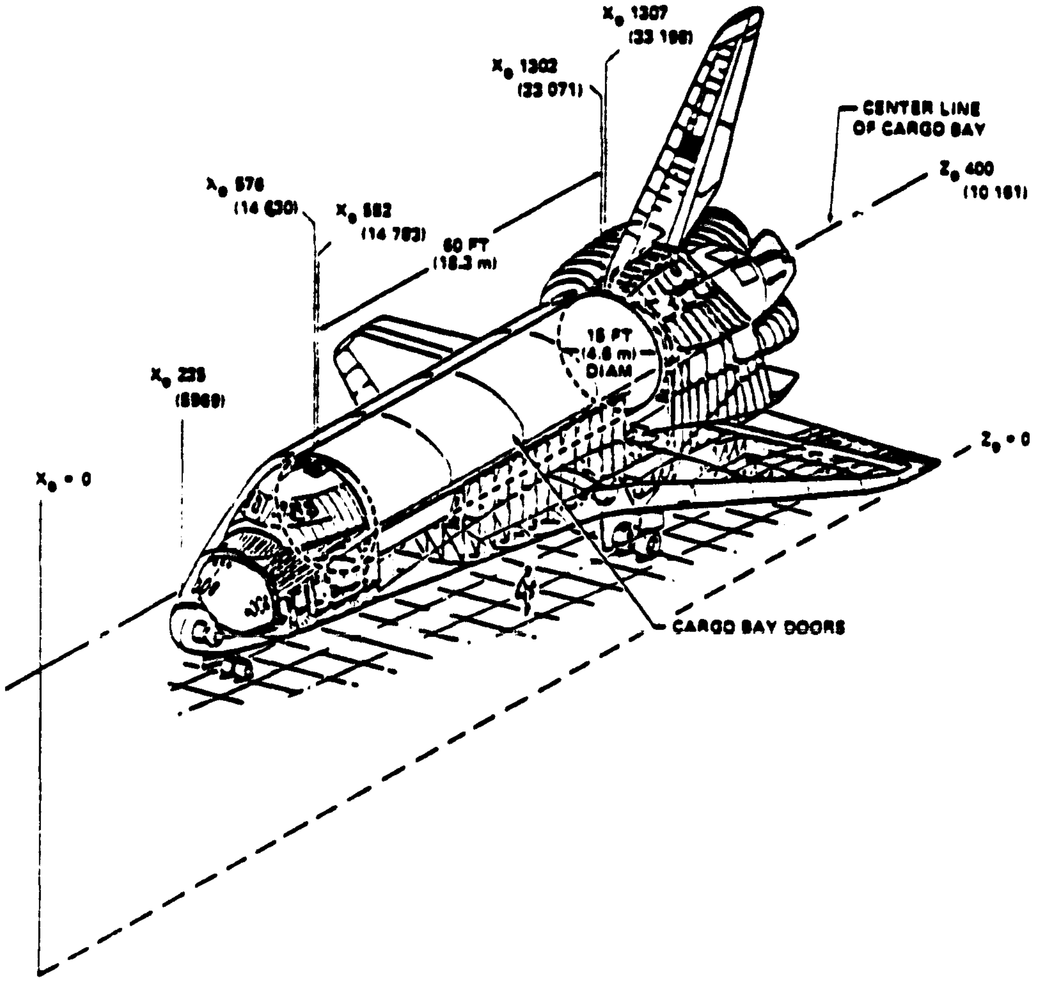

Figure 3-19. Payload bay envelope.

The cargo bay is covered with doors that open to expose the entire length and full width of the cargo bay. The usable envelope is limited by items of supporting subsystems in the cargo bay that are charged to the payload volume, e.g., one OMS kit reduces available length to 50.2 feet (15.3m).

The payload clearance envelope in the Orbiter cargo bay measures 15 by 60 feet (4572 by 18 288 millimeters). This volume is the maximum allowable payload dynamic envelope, including payload deflections. In addition, a nominal 3-inch (76-millimeter) clearance between the payload envelope and the Orbiter structure is provided to prevent Orbiter deflection interference between the Orbiter and the payload envelope as shown in Figure 3-20. Payload coordinates are given in Figure 3-21.

The payload space on the aft flight deck is intended primarily for control panels and storage. Area and volume available for payload equipment are shown in Figure 3-22.

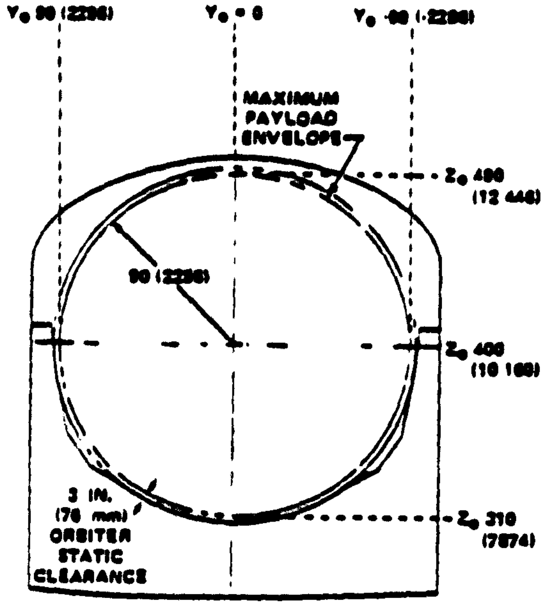

Figure 3-20. View of payload envelope looking aft.

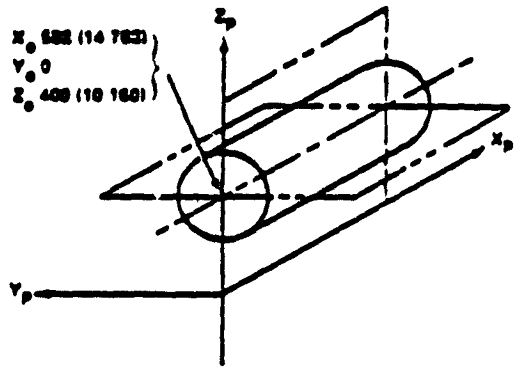

Figure 3-21. Payload coordinates.

b. Weight and Center of Gravity. The location of the cargo center of gravity is critical during aerodynamic flight. Weight and center-of-gravity calculations must take into account all items of supporting subsystems charged to the payload. Cargo center-of-gravity envelopes for each axis of the Orbiter are shown in Figures 3-23, 3-24, and 3-25. During normal landing and abort operations, the center of gravity must fall within these envelopes. Out-of-envelope conditions are permissible during launch and space flight. However, the conditions must be correctable before reentry or in the event of an abort on launch. (U,H

Each proposed out-of-envelope condition will be evaluated individually.

c. Structural Interfaces. Numerous attachment points along the sides and bottom of the cargo bay provide structural interfaces in a multitude of combinations to accommodate payloads. Thirteen primary attachment points along the sides accept X and Z-axis loads. (See Figure 3-26.) Twelve positions along the keel take lateral loads. (See Figure 3-27.) Vernier locations are provided on each bridge fitting. (U,H

The fittings are designed to be adjusted to specific payload weight, volume, and center-of-gravity distributions in the bay. The fittings to attach payloads to the bridge fittings are standardized to minimize payload changeout operations. To further minimize payload operations involving the Orbiter, standard payload handling interfaces have been provided.

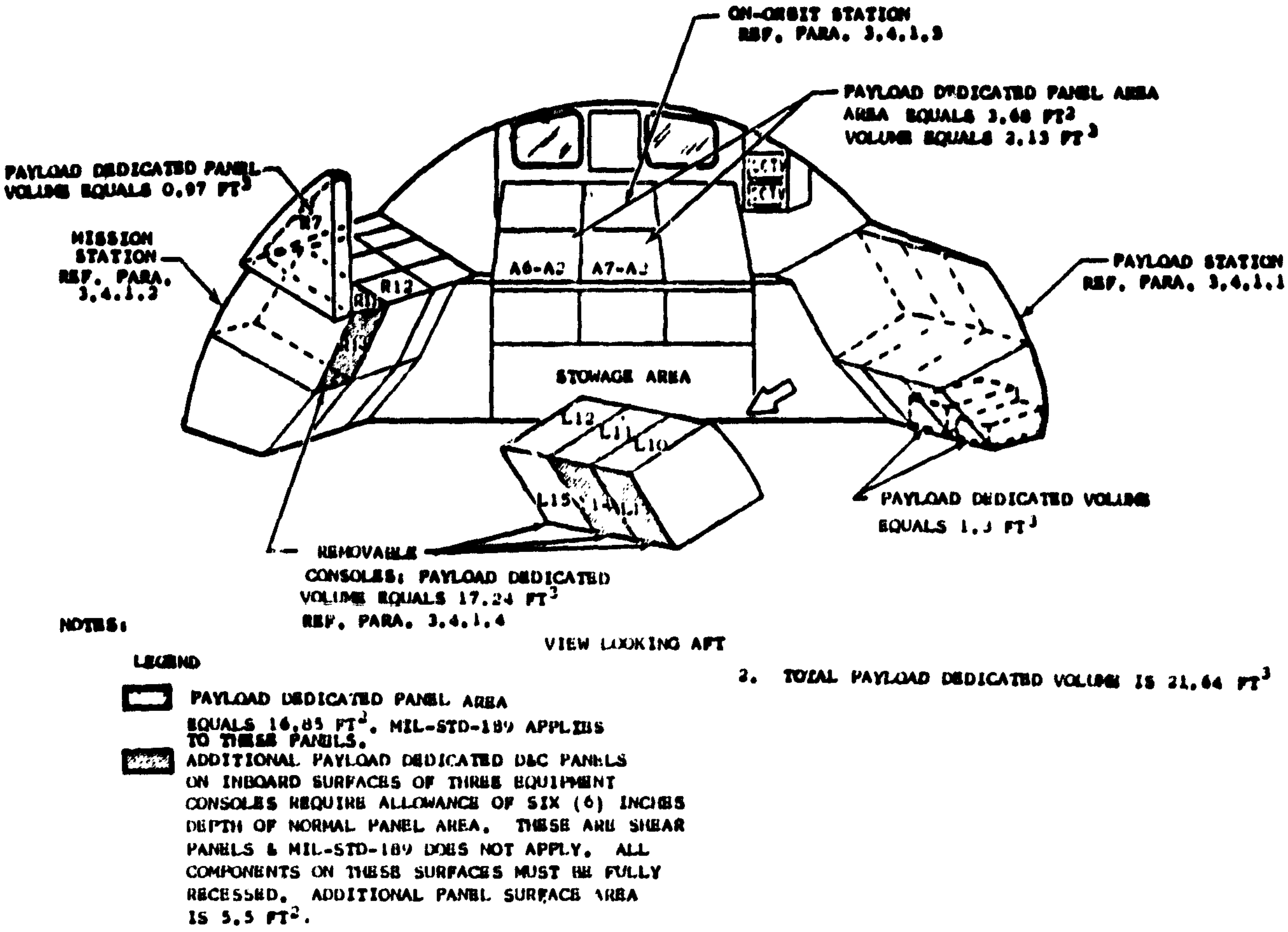

Figure 3-22. Aft cabin provisions for payload equipment and controls.

(U.H.) (except as noted) 3.6.1.3 <u>Environmental.</u> Payload environments will vary for specific missions and will also depend on the payload configuration; therefore, data in this section are general in nature. The figures represent recommended design qualification test levels.

More detailed description of environmental criteria can be found in JSC 07700, Vol. XIV, and ICD 2-19001.

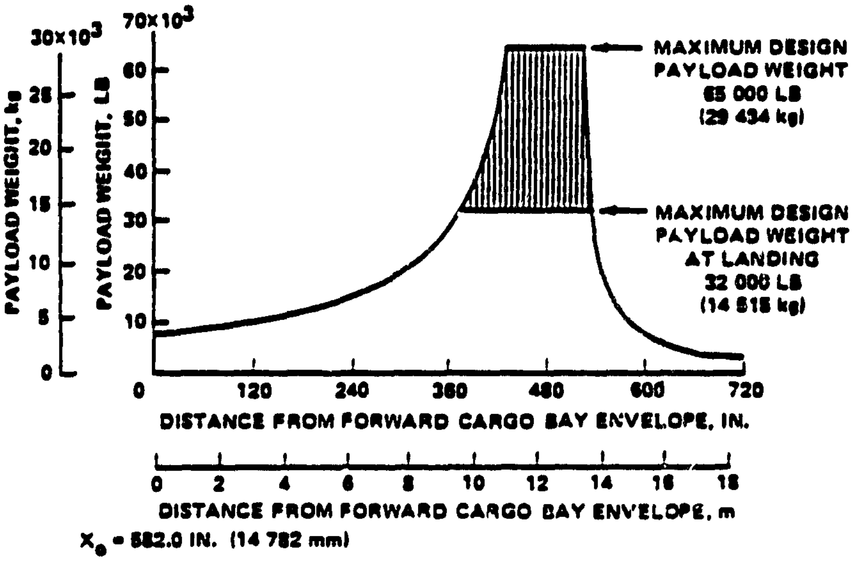

Figure 3-23. Payload center-of-gravity limits along the Orbiter X-axis.

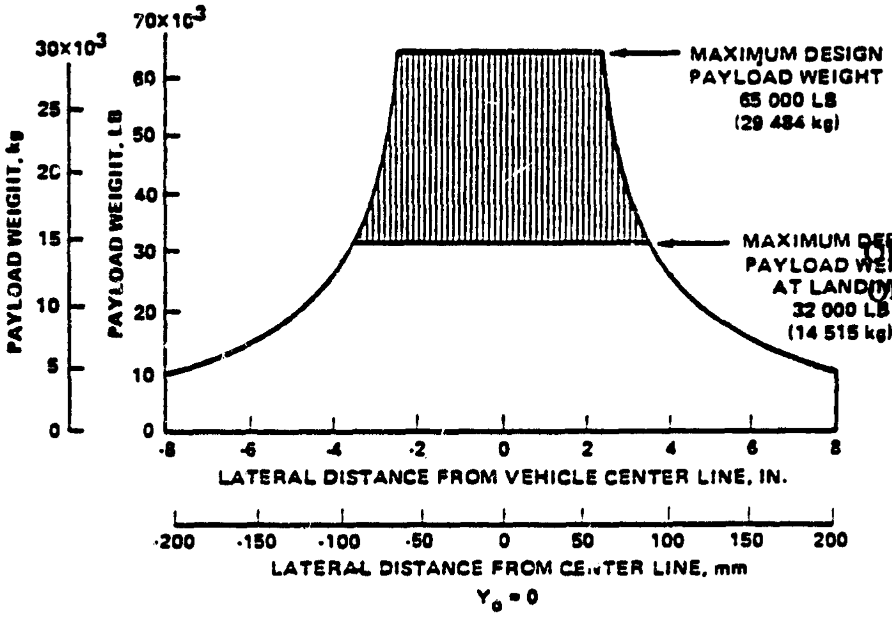

Figure 3-24. Payload center-of-gravity limits along the Orbiter Y-axis.

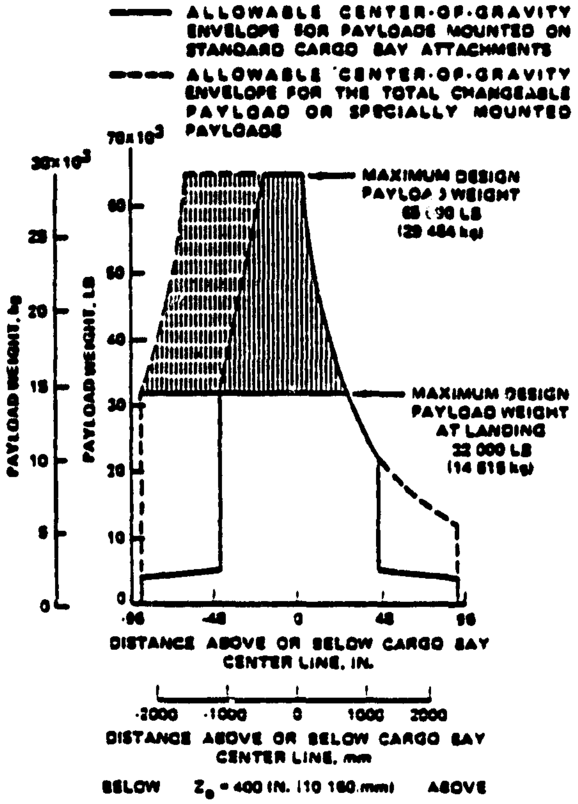

Figure 3-25. Payload center-of-gravity limits along the Orbiter Z-axis.

a. Vibration. The Orbiter is subjected to random vibration on its exterior surfaces by acoustic noise (generated by the engine exhaust) and by aerodynamic noise (generated by airflow) during powered ascent through the atmosphere. These fluctuating pressure loads are the principal sources of structural vibration. Actual vibration input to payloads will depend on transmission characteristics of midfuselage payload support structure and interactions with each payload's weight, stiffness, and center of gravity.

The estimated random vibration and appropriate exposure durations for the cabin and midfuselage to payload interfaces caused by the fluctuating pressure loads are shown in Figure 3-28. The levels shown are typical of liftoff, transonic flight, and performance at maximum aerodynamic pressure. The midfuselage/payload interface vibration environment is based on the response of unloaded interface structure and should be considered the upper limit. The vibration inputs at the interface will be reduced by addition of the payload and support structures between the interface and payload component.

(JSC 07700, I/F Spec)

b. Acoustic. Vibration resulting from acoustic spectra is generated in the cargo bay by the engine exhaust and by aerodynamic noise during atmospheric flight. These predicted maximums are illustrated in Figure 3-29. The data presented are based on an empty cargo bay and may be modified by the addition of payloads, depending on their characteristics.

Equipment that is mounted in the aft flight deck will be subjected to the acoustic spectra given in Figure 3-30.

The spectra illustrated in the preceding two figures represent the maximum levels, which occur 2.5 seconds after liftoff. These levels will vary with time during the launch and early flight as shown in Figure 3-31.

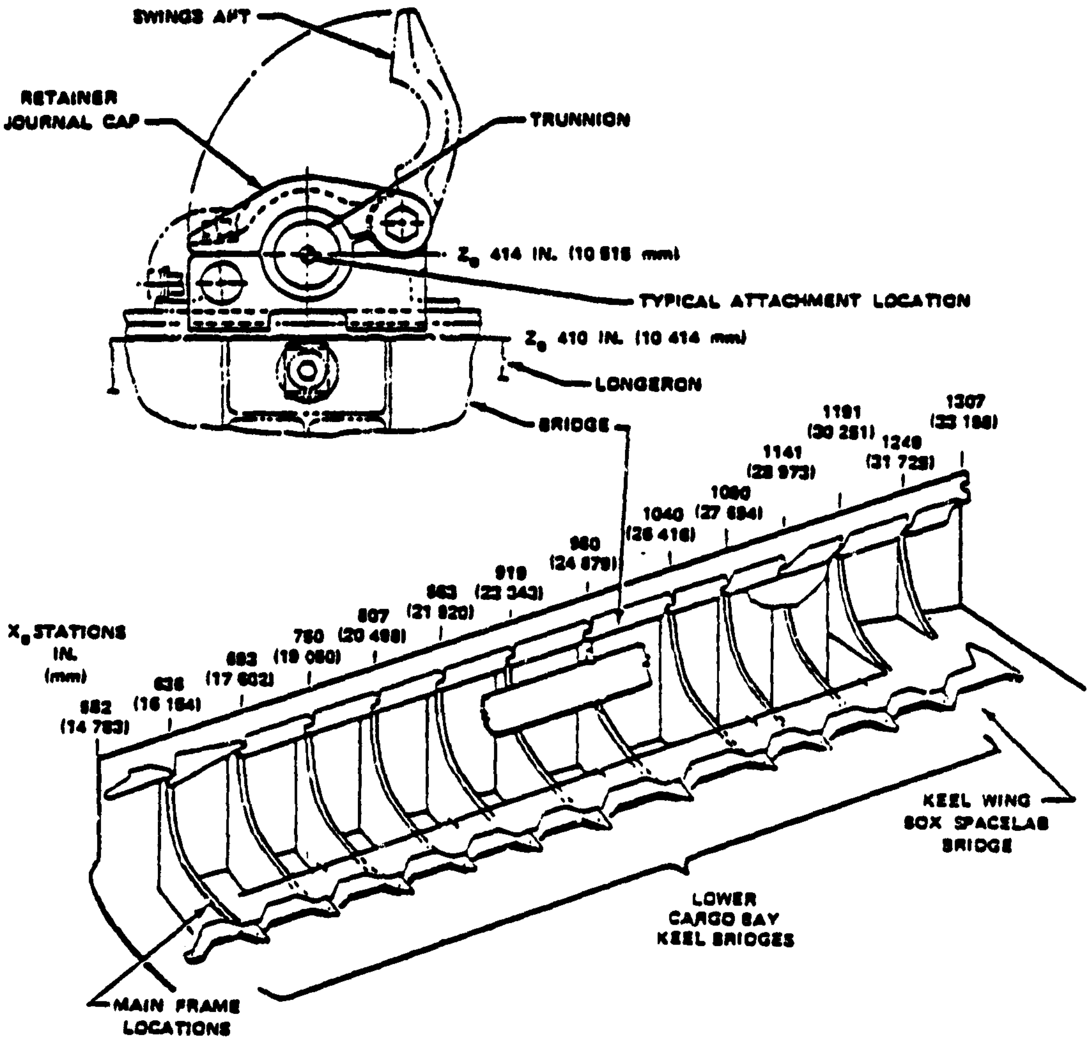

Figure 3-26. Payload structural attachment locations and standard fitting detail.

c. Thermal. During ground operations, the thermal environment of the cargo bay is carefully controlled by purging. While the Orbiter is on the ground, the cargo bay can be controlled within the limits shown in Table 3-13. Air-conditioning and purge requirements are defined by analysis for each launch. (U.H

The purge gas will be nominally class 100, guaranteed class 5000 (HEPA) filtered with 15 ppm or less hydrocarbons based upon a methane equivalent. (JSC 07700 4.2.1.

The level of cleanliness maintained at preflight on the payload and payload bay will be retained through launch to orbital insertion including liftoff, orbital insertion, etc. (JSC 07700 4.3.4.5

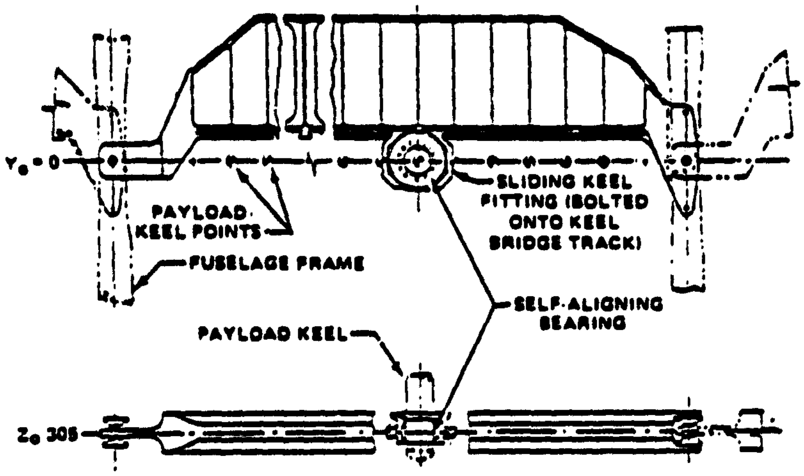

Figure 3-27. Keel bridge and attachment interface.

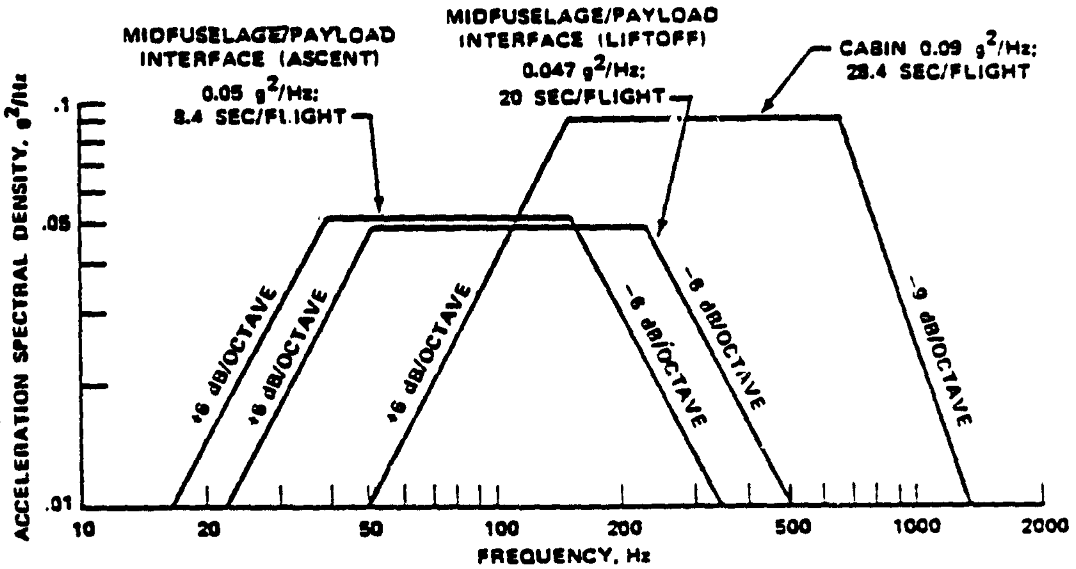

Figure 3-28. Payload interface and cabin random vibration.

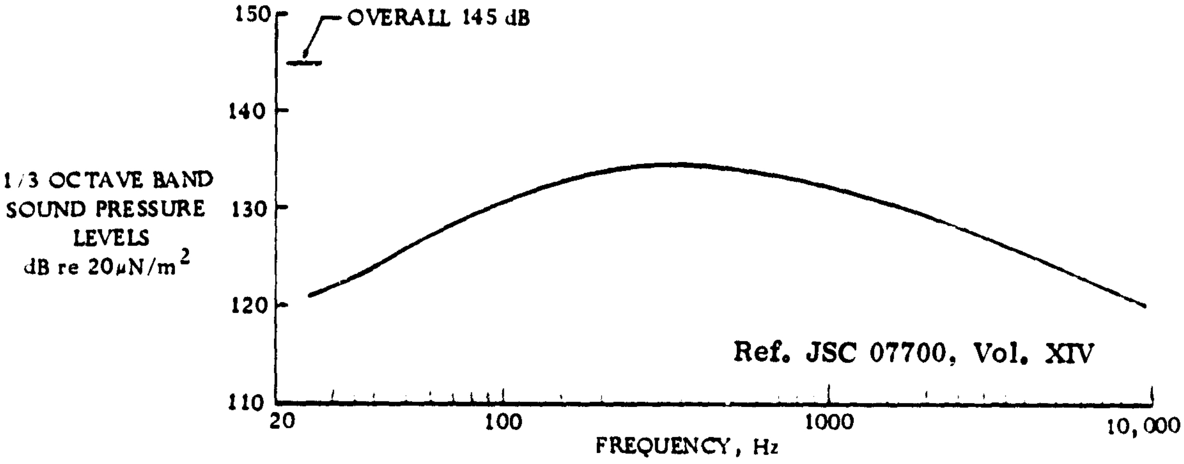

Figure 3-29. Maximum predicted cargo bay internal acoustic spectra.

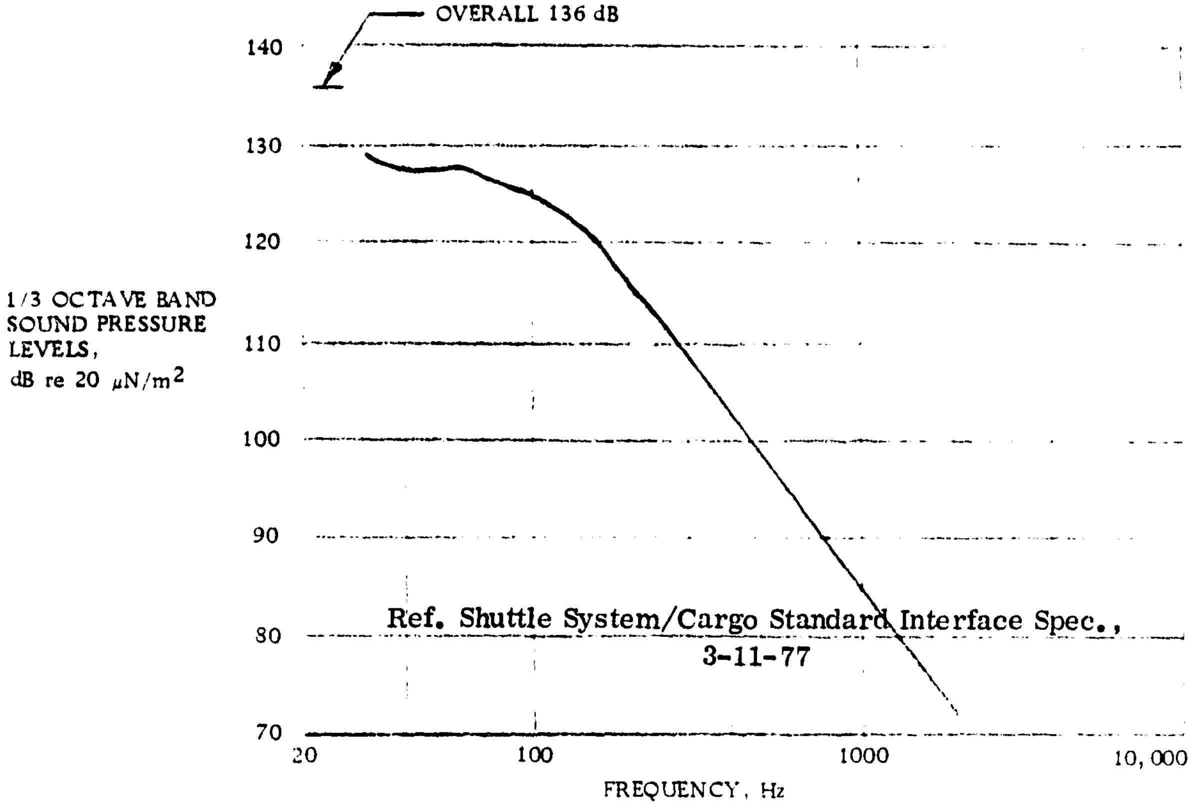

Figure 3-30. Maximum aft flight deck acoustic spectra.

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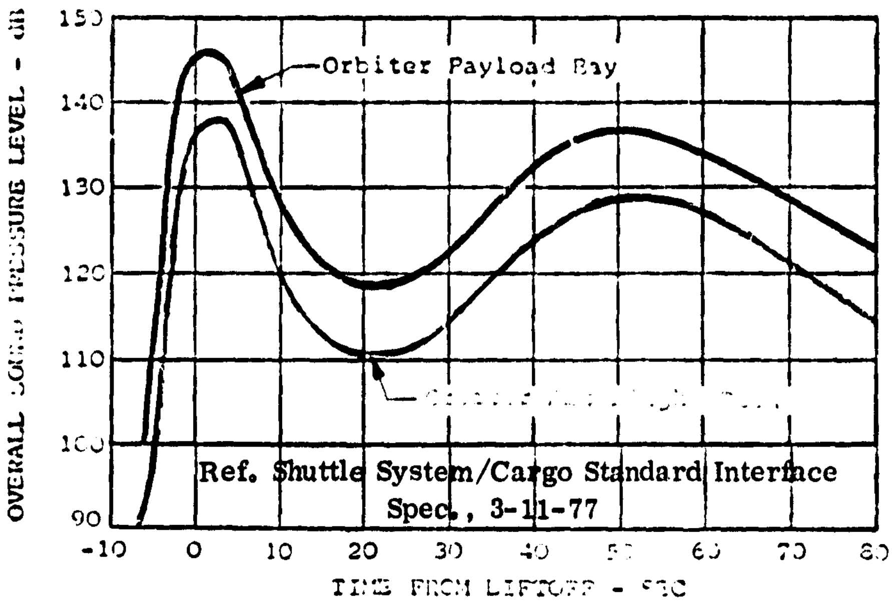

Figure 3-31. Overall sound pressure level time history.

Table 3-13. Ground purge capability.

Parameter	Location			
	Before launch pad		Postlanding and runway to OPF*	Transfers (VAB† to OPF, VAB to pad, OPF to VAB)
	Noncryogenic Payload	Cryogenic Payload		
Gas type	Air/GN_2**	GN_2	Air	Air
Temperature range, ±2°F (±1.1 K) (at T-0 umbilical inlet)	45 to 100 (280 to 311)	45 to 100 (280 to 311)	45 to 100 (280 to 311)	65 to 85 (291 to 303)
Flow rate, lb/min (kg/min)				
Spigots closed	110 (50)	364 (165)	115 (52)	115 (52)
Spigots open				
Spigots	150 (68)	150 (68)	136 (62)	136 (62)
Manifold	110 (50)	215 (97)	101 (46)	101 (46)
Total (spigots open)	260 (118)	364 (165)	220 (100)	220 (100)
Supply pressure, psig (N/m^2)	2.5 (17 235)	10 (68 940)	2.0 (13 788)	2.0 (13 788)

*OPF = Orbiter Processing Facility.
†VAB = Vehicle Assembly Building.
**Initiate gaseous nitrogen (GN_2) purge 80 min before cryogenic tanking to inert cargo bay.

During the ascent trajectory, the Orbiter construction and insulation limit the Orbiter-induced heat loads on the payload. At 600 seconds after launch, the Orbiter is in the on-orbit phase and the cargo bay doors can be opened. (U.H.

In space, with the cargo bay doors open, heating of payload components is based on the thermal, thermophysical, and geometric characteristics of each component. Additional factors influencing the incident thermal environment are launch date and hour, vehicle orientation, and orbital attitude. A detailed analysis of each payload may be necessary before thermal design and integration. For preliminary calculations, the optical properties of the cargo bay liner, Orbiter radiators, and insulated forward and aft bulkhead surfaces are: (U.H.

Cargo bay liner	$\alpha/\epsilon \leq 0.4$
Radiator surface	$\alpha/\epsilon = 0.10/0.76$
Forward and aft bulkheads	$\alpha/\epsilon \leq 0.4$

where α is absorption and ϵ is emissivity.

Cargo temperatures for a typical flight, with emphasis on the entry phase, are shown in Figure 3-32.

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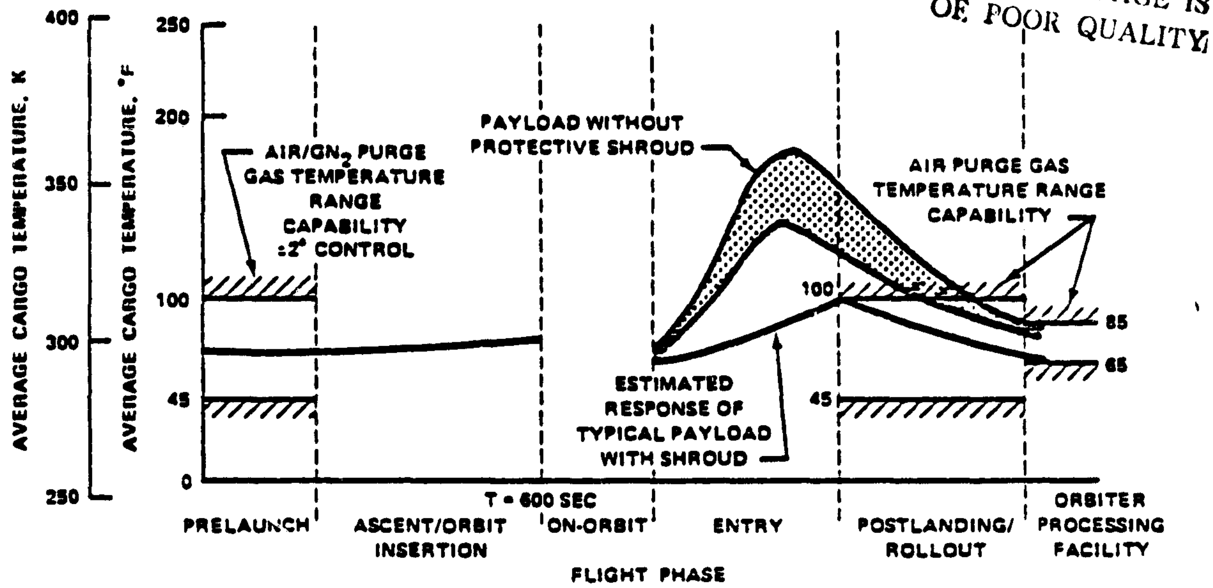
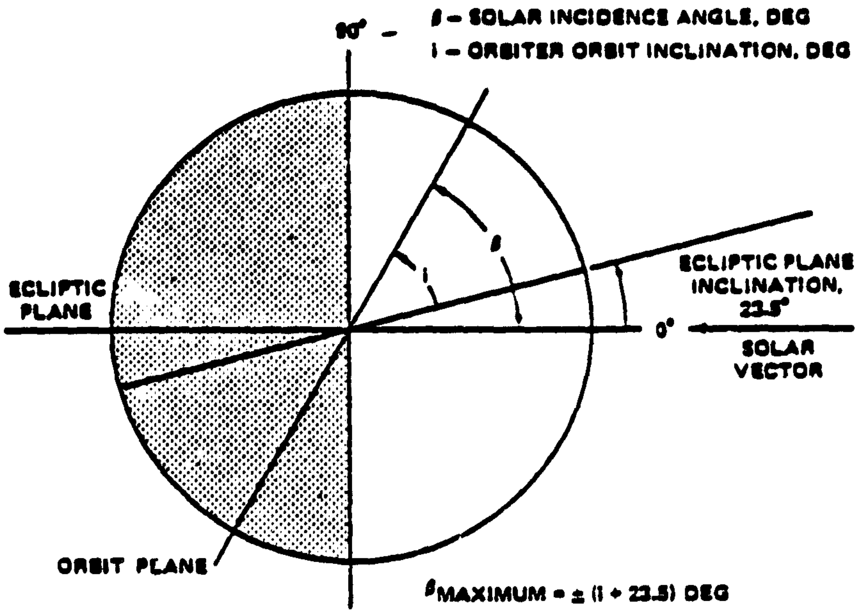


Figure 3-32. Cargo bay thermal environment vs. flight phases.

The Orbiter is designed for attitude hold capabilities as shown in Figure 3-33. During the 3-hour thermal conditioning periods, the vehicle rolls at approximately five revolutions per hour (barbecue mode) about the X-axis with the orientation of the X-axis perpendicular to the Earth-Sun line within ±20°, or it can be oriented at preferred thermal attitudes. On-orbit thermal conditioning lasting as long as 12 hours (before the deorbit maneuver) is allocated for missions on which the thermal protection subsystem temperatures exceed the design limits associated with a single-orbit mission. (U.H.



β range, deg	Orbiter orientation	Hold capability, hr	Preentry thermal conditioning requirements, hr
0 to 60	Any	≥160	≤12
60 to 90	Other than 3-axis inertial holds	Cycles of 6-hour holds followed by 3 hours of thermal conditioning for worst thermal attitudes	≤7
	3-axis inertial holds	≥160	≤12

Figure 3-33. Orbiter attitude hold capabilities for various vehicle orientations.

(U.H.) d. Pressure. With the vents open, the cargo bay pressure closely follows the flight atmospheric pressures. The payload vent sequencing is as follows:

Prelaunch	Closed (vent No. 6 in purge position)
Liftoff (T = 0)	Closed
T + 10 seconds	All open
Orbit insertion	All open
Preentry preparation	All closed
Entry (high heat zone)	All closed
Atmospheric (75,000 ± 5,000 feet (23 ± 1.5 kilometers)) to landing	All open
Postlanding purge	Closed (vent No. 6 in purge position)

During the orbital phase, the cargo bay operates unpressurized. Pressures for other flight phases are shown in Figure 3-34.

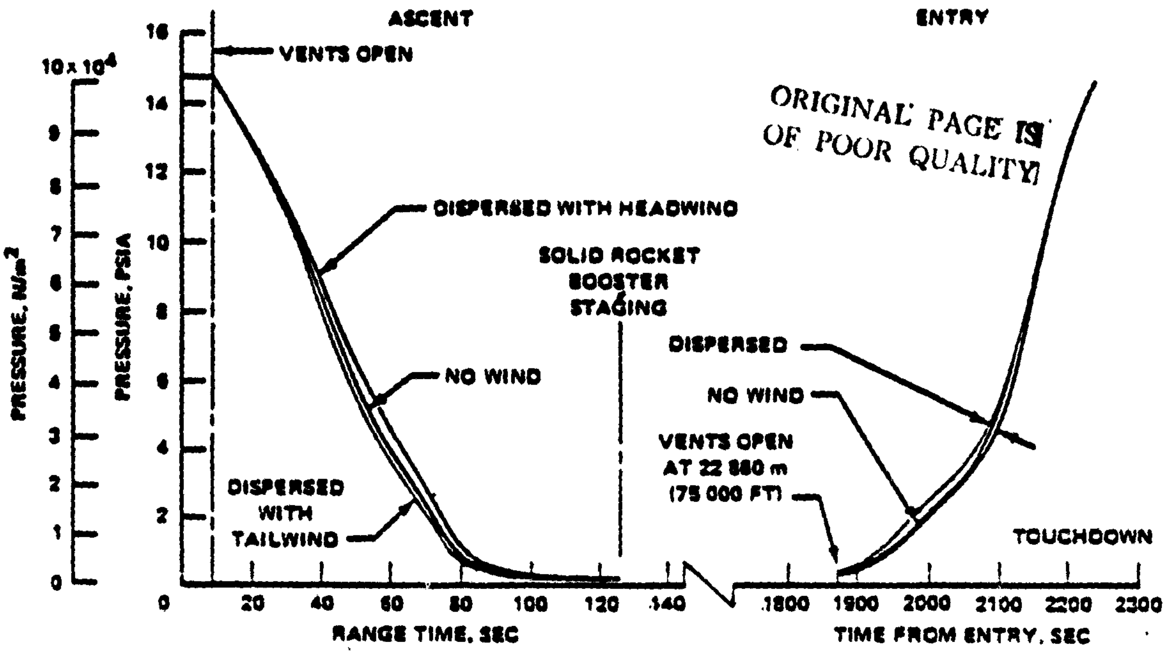


Figure 3-34. Cargo bay internal pressure.

e. Contamination Control. Contamination control systems as well as various techniques to eliminate or minimize contamination are provided by the Orbiter design and standard flight plans. The sensitivity of most payloads to contamination is recognized and each mission can be tailored to meet specific requirements. Before liftoff and after landing, the cargo bay is purged and conditioned as specified in the description of thermal controls. At launch and during early ascent, the cargo bay vents are left closed to prevent exhaust products and debris from entering the bay. During final ascent and through orbit insertion, the cargo bay is depressurized and the payload is generally not subjected to contaminants. (U.H

On orbit, there are three major sources of contamination: reaction control system vernier firings, dumping of potable water, and release of particulates and outgassing. Predicted column density and return flux contributions are shown in Table 3-14.

During deorbit and descent, the cargo bay vents are closed to minimize ingestion of contaminants created by the Orbiter systems. During the final phase of reentry, the vents must be opened to repressurize the Orbiter. To help prevent contamination during this phase, the vents are located where the possibility of ingestion is minimal.

Table 3-14. Predicted column density and return flux.

Source	Number column density, molecules/cm^2			Return flux, molecules/cm^2/sec		
Outgassing (a) and (b)	$< 10^{12}$ after 10 hr			$\leq 10^{12}$		
				Values at 253 n. mi. (435 km)		
Vernier RCS	Aft -Z	Aft Y	Forward X/Z	Aft -Z	Aft Y	Forward Y/Z
(a)	4.4×10^{14}	2.0×10^{14}	3.9×10^{12}	7.6×10^{12}	3.4×10^{12}	6.6×10^{10}
(b)	1.8×10^{14}	8.1×10^{13}	2.7×10^{12}	3.2×10^{12}	1.4×10^{12}	4.8×10^{10}
Flash evaporator				378 n.mi. (700 km)	235 n. mi. (435 km)	108 n. mi. (200 km)
(a)		5.6×10^{12}		8.4×10^{8}	2.4×10^{12}	1.3×10^{12}
(b)		5.6×10^{12}		8.5×10^{8}	2.4×10^{10}	1.3×10^{12}
Leakage						
(a)		2.2×10^{13}		1.2×10^{10}	3.7×10^{11}	1.9×10^{13}
(b)		3.5×10^{13}		2.0×10^{10}	5.6×10^{11}	3.1×10^{13}

[a]Zero degree line-of-sight (in the $+Z_0$ direction) originating at X_0 1107.

[b]50° off of +Z towards $-X_0$ (forward) originating at X_0 1107.

(U.H.) f. Acceleration. Payload structure and substructure must be designed with the appropriate margin of safety to function during all expected loading conditions, both in flight and during ground handling. The limit load factors at the payload center of gravity are shown in Table 3-15. The recommended maximum margin of safety to apply to these limit load factors is 1.4. Emergency landing loads shall be carried through the payload primary structure at its attachment fittings. Preliminary design criteria for emergency landing conditions (ultimate design accelerations) for linear g are: along the X-axis, +9.00 to -1.50; along the Y-axis, +1.50 to -1.50; and along the Z-axis, +4.5 to -2.0.

The emergency landing design accelerations are considered ultimate; therefore, a 1.0 margin of safety should be applied.

(U.H.) g. Landing Shock. Landing shock is another factor that must be considered in payload structure design. Rectangular pulses of peak accelerations will be experienced, as shown in Table 3-16.

Consideration should be given to analyzing the landing shock environment in lieu of testing, because the g levels are relatively low in comparison to the basic design shock.

Testing must be performed only on those items not covered in a static structural stress analysis.

Table 3-15. Limit load factors*.

Condition	Load factor		
	X-axis	Y-axis	Z-axis
Liftoff	-0.1 -2.9	1.0 -1.0	1.5† -1.5†
Booster staging	-2.7 -3.3	.2 -0.2	-0.3 -0.3
Entry	1.06 -0.02	1.25 -1.25	2.5 -1.0
Landing	1.0 -0.8	0.5 -0.5	2.8† 2.2†

*For 65,000 lb (29 484 kg) up and 32,000 lb (14 515 kg) down.

†Angular accelerations of 10 rad/sec^2 applied from front cradle support to free end of spacecraft.

i.e. $N_Z = +2.75 + \frac{10\Delta X}{386}$, $N_Z = -2.75 - \frac{10\Delta X}{386}$

Table 3-16. Landing shock peak accelerations.

Acceleration, g peak	Duration, msec	Applications per 100 flights
0.23	170	22
.28	290	37
.35	330	32
.43	360	20
.56	350	9
.72	320	4
1.50	260	1
		125

h. Electromagnetic Compatibility. In general, close adherence to accepted electromagnetic compatibility design requirements will ensure compatibility of payloads with the Orbiter. The payload-generated, -conducted, and -radiated emissions are limited to the levels specified in Figures 3-35, 3-36, and 3-37.

The limits to power line narrowband emission levels shown in the figures may be exceeded when the payload is operating from a dedicated fuel cell, provided the radiated electric field emission limits shown are met.

The magnetic fields (applied at a distance of 1 meter) generated shall not exceed 130 decibels above 1 picotesla (30 to 2 hertz), falling 40 decibels per decade to 50 kilohertz. The dc field shall not exceed 160 decibels above 1 picotesla.

The maximum radiated electric fields, applied at a distance of 1 meter, both for narrowband and broadband emissions, are shown. In addition, for payload equipment in the cargo bay, broadband emissions shall be limited to 70 decibels above 1 μV/m/MHz in the frequency range of 1770 to 2330 megahertz; narrowband emissions shall be limited to 25 decibels above 1 μV/m from 1770 to 2300 megahertz, excluding intentional payload transmissions.

Electrostatic discharges are not permitted within the cargo bay unless they are contained and shielded by the payload.

Payload-generated power by single event switching or operations occurring less than once per second shall not generate transients 300×10^{-6} voltseconds above or below normal line voltage when fed from a source impedance as shown. Peaks shall be limited to ±50 volts, and rise and fall times shall not be less than 1 microsecond.

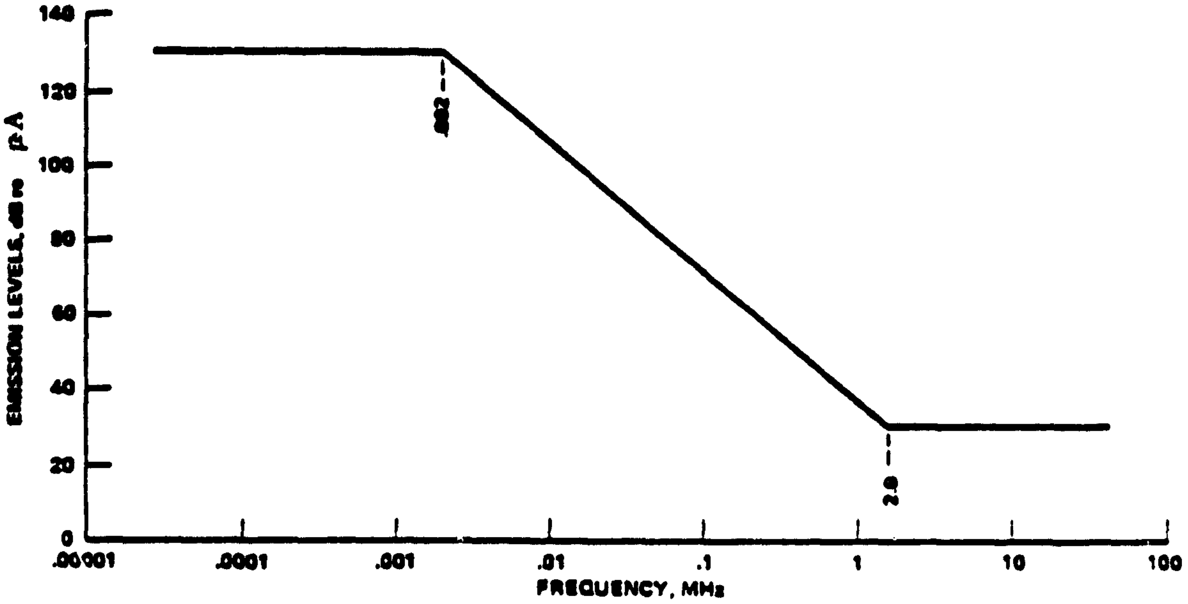


Figure 3-35. Payload allowable conducted narrowband emissions.

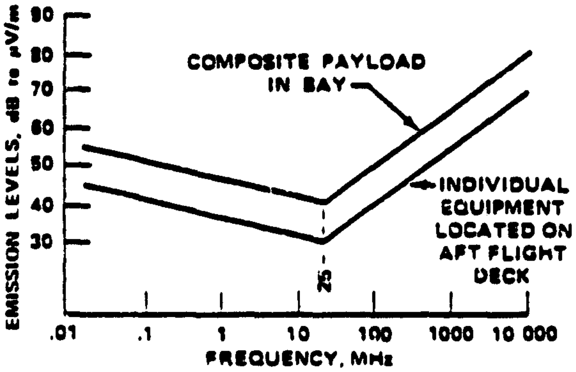


Figure 3-36. Payload allowable radiated narrowband emissions.

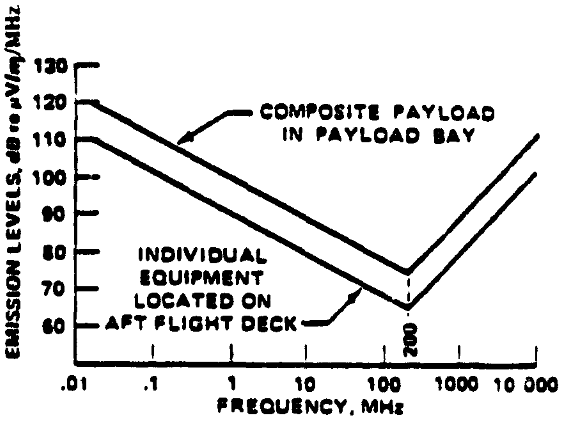


Figure 3-37. Payload allowable radiated broadband emissions.

3.6.1.4 Operations.

(U.H.) a. Flight Planning. Flight planning is an ongoing process; it involves the specific user at the point when payload mission-planning activities are integrated with the STS operations planning. The STS operations organization is responsible for all STS planning except payload-specific planning, which is done by the user.

The payload mission plan is provided by the user and is necessary for integrating the payload planning and STS flight-planning activities. It is fundamental to the payload flight assignment, obtaining the STS flight profile design, and subsequent crew activity planning.

The time needed for the planning cycle is related to the complexity of a flight as well as to the number of times a given type of flight has already occurred. The basic objective for STS operations is to achieve a short (16 weeks) detailed planning cycle for simple or repeat-type flights. The first few times a new type of flight is planned, a longer planning cycle is required for developing standardized phases (which can then be used in planning later similar flights). Planning of standard flight types and flight phases has been underway for several years. Longer planning cycles of individual flights are also needed for those complex flights involving analysis and multidiscipline coordination.

Real-time revision of plans (such as consumables management, updates to procedures, or changes in crew activities) during a flight is a natural continuation of the preflight planning process.

The following five interdependent elements, all related to payload flight planning, make up STS flight planning.

- Utilization planning — the analysis of approved (funded or committed) payloads with operational resources, leading to a set of firm flight schedules with cargo manifests.
- Flight design — detailed trajectory, attitude, and pointing planning (among other parameters), which becomes part of the basic flight profile.
- Crew activity planning — the analysis and development of required activities to be performed in flight, resulting in a set of crew activity procedures and time lines for each flight.
- Operations planning — performing those tasks that must be done to ensure that vehicle systems and ground-based flight control operations support flight objectives.
- Training preparation — those activities required to assure that the proper resources are available to train the flight crew and flight operations support personnel to perform their assigned tasks.

The user's responsibilities in support of launch site operations are defined through standard interfaces and documentation sequences summarized here. The basic document is the KSC Launch Site Accommodations Handbook for STS Payloads (K-STSM-14.1). A launch site support manager (LSSM) will be assigned early in the planning program and will be the primary interface with the user.

(U.H.) b. Ground Operations.

1. Before Mating With STS. Processing of a payload at the launch site can usually be divided into two distinct phases: those activities performed before the payload is mated with an STS element and those activities involving one or more of the STS elements (Shuttle vehicle, Spacelab, upper stage).

The typical operations that must be performed to ready a payload for launch on a Shuttle vehicle will vary according to the complexity of the payload, the technical disciplines involved, and the level of testing already done before the payload arrives at the launch site.

Because of the 160-hour turnaround constraint for preparing Space Shuttle Orbiters for launch, integration of payloads with the Orbiter will be limited to mandatory tasks. A payload element should be delivered to the launch site in as near flight-ready condition as is practical. Typical prelaunch operations include receiving, assembling, checking out, servicing, and preparing for integration with other payload elements. Preparation and testing will not follow a fixed plan for all payloads.

The launch site activity plans must be established before arrival of a specific payload at the site to assure satisfactory completion of all flight-readiness preparations, including integration into a total cargo. The schedule will identify all major tests, all hazardous (systems) operations, interface verification, and all operations that require launch site services.

Individual payloads will be integrated into a single cargo before mating and checkout with the Orbiter. The integration testing of the total cargo will include a Shuttle interface verification test, using the cargo integration test equipment, before the mating of cargo and Orbiter. This test is critical to the overall operation because Shuttle on-line operations assume compatibility between the cargo and the Shuttle system.

Customized STS/payload time lines, negotiated through the LSSM, will be part of the launch site support plan for a particular payload.

(U.H.) 2. Mating of Payload With STS. Those operations required to prepare the Orbiter for payload installation are performed in parallel with the Orbiter systems checkout. These payload-related operations include installation of any payload accommodations modification kits assigned for the flight. Then payload/STS operations can begin.

Payload operations involving the Shuttle (Figure 3-38) begin with the actual payload installation, either at the Orbiter Processing Facility (OPF) or at the launch pad (using the payload changeout room). Allocated times shown are approximate only. The lines marked as reference indicate STS processing that does not involve the payload; they are shown to acquaint users with the overall ground flow.

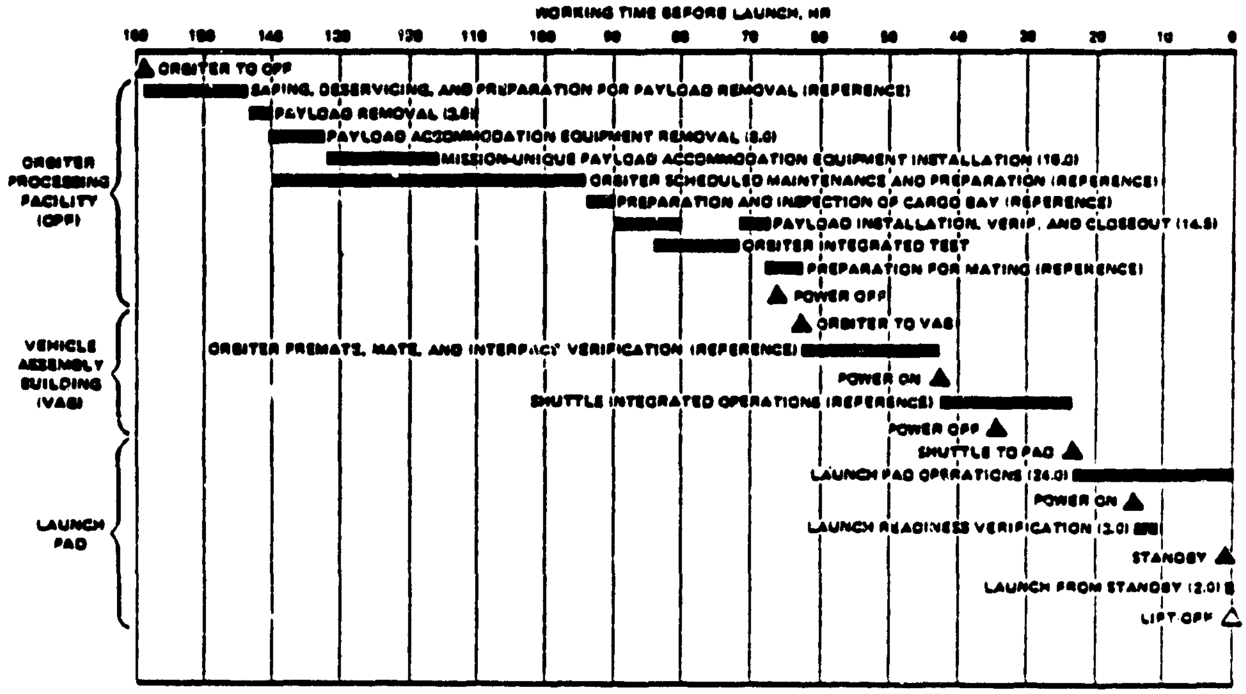


Figure 3-38. Typical payload installation schedule at the OPF.

Payloads installed horizontally are put into place in the OPF at this time. They are hoisted into the cargo bay and secured. Interfaces are connected and verified. Then an Orbiter integrated test is conducted to complete the verification of interfaces between the payload and Orbiter. This test includes validation of payload data via Orbiter data systems, if applicable.

After the cargo bay doors are closed, the payload environment will be maintained to the Vehicle Assembly Building and then to the launch pad. There will be a period of approximately 40 hours during Orbiter hoisting operations in the VAB when the environmental purge will be interrupted.

At the VAB, the Orbiter is hoisted to a vertical position, transferred to an integration cell, and lowered and mated to the external tank and solid rocket boosters. After the Orbiter aft umbilicals have been connected, a Shuttle interface test is conducted to verify vehicle/facility interface compatibility and readiness.

No payload activities will be done in the VAB except those required for housekeeping; for example, monitoring of a potentially hazardous system. Electrical power will not be available for payloads from the Orbiter during tow to the VAB, Orbiter erection in the VAB, and transfer to the launch pad.

The integrated Shuttle vehicle is transferred to the launch pad on the mobile launch platform. The vehicle and platform are mated to the pad and the interfaces are verified.

Payloads that require vertical installation are moved to the launch pad in an environmentally controlled canister the same size as the Orbiter cargo bay. At this time, those payloads are installed in the Orbiter by the pay-

load ground handling mechanism in the payload changeout room. Environmental control is maintained during the installation and the Orbiter-to-payload interfaces are verified.

A launch-readiness test verifies the integrity of the pad/Shuttle/payload system interfaces for launch. Hypergolic, fuel cell cryogenic, and pneumatic systems are serviced, and countdown preparations continue until 2 hours before launch. At that time the Shuttle cryogenic propellants are loaded, the flight crew boards, and final countdown is begun.

(U.H.) 3. Launch Site Facilities and Services. The payload assembly and test areas, launch complexes, and other specialized facilities will be used for payloads during prelaunch preparations. The user can obtain detailed information about the facilities required from the LSSM. The LSSM will ensure that appropriate facilities are assigned to meet individual needs.

Various specialized facilities are intended primarily for processing of payloads before they are mated to the STS. Others are primarily for processing STS elements (Orbiter, Spacelab, upper stages) or for payload integration and simulated Orbiter interface verification. Both categories are summarized in Tables 3-17 and 3-18. Facility environments are summarized in Table 3-19.

Table 3-17. STS Process Facilities.

Facility	Location	Primary uses	Other uses
Operations and Checkout Bldg.	KSC industrial area	1. Spacelab refurbishment 2. Spacelab processing 3. Horizontal cargo integration	1. Special purpose laboratories 2. Office space
SAEF-1	KSC industrial area	1. Upper stage processing 2. Vertical cargo integration	
OPF	Launch complex 39 area	1. Orbiter refurbishment 2. Payload installation and interface verification	
VAB	Launch complex 39 area	1. Shuttle assembly	1. Office space
Launch pad	Launch complex 39 area	1. Shuttle launch 2. Payload installation and interface verification	

(U.H.) 4. Cargo Support Equipment. A variety of equipment is available at the launch site for processing payloads. Interfaces are shown in Table 3-20. The user should identify his needs to the LSSM as early as possible. Unique payload ground-support equipment must be provided by the user and should be identified, controlled, and funded by the user's organization or development agency. Interfaces to this equipment at the launch site should be planned with the LSSM.

Table 3-18. Payload processing facilities.

Facility	Location	Primary uses	Other uses
Hangar S	Cape Kennedy Air Force Station	1. Spacecraft processing	1. Ground station area 2. Office space
Hangar AE	Cape Kennedy AF Station	1. Spacecraft processing	1. Ground station area 2. Office space
Hangar AM	Cape Kennedy AF Station	1. Spacecraft processing	1. Ground station area 2. Office space
Hangar AO	Cape Kennedy AF Station	1. Spacecraft processing	1. Ground station area 2. Office space
Explosive safe area 60A	Cape Kennedy AF Station	1. Spacecraft hazardous systems processing	
Propellant lab		1. Propellant fueling	1. Ordnance operations 2. Pressurization operations
Spacecraft Assembly Bldg.		1. Ordance operations	1. Propellant pressurization operations 2. Encapsulation activity
Delta Spin Test Bldg.	Cape Kennedy AF Station	1. Spacecraft hazardous systems processing	

(a) Transportation equipment. The standard transportation equipment (Figure 3-39) is designed to protect the payload enroute to the launch site. The payload is protected from contamination by a static-free, clean bag, which encloses the payload before it is attached to an adapter assembly. The air is evacuated so the bag will cling to the payload surface.

The supporting adapters are attached to the payload at normal flight interfaces and to the containers in a universal mounting pattern. A special damping material between the adapter and the container platform shock-isolates the payload. These adapters will not impose g-loads to the payload structure greater than those imposed by the Orbiter. Three adapters are used: one end-mounted and two types of Spacelab pallet adapter (for horizontal and vertical transport).

Tiedowns, which interface with universal tiedown rings and commercial carrier tiedowns, are provided. A sling set is provided to be used with cranes or hydraulic hoists to handle the loaded containers and the self-contained environmental and power units. The same slings are used to rotate a pallet when it is to be transported horizontally.

A transport environment monitoring system (TEMS) will be required to sense shock, vibration, temperature, humidity, and power levels of the payload. An alarm system in both the tractor cab and an escort vehicle would provide warning if any critical parameters are out of tolerance. In addition, engineering data on these same parameters would be continuously recorded to determine the acceptability of the payload shipment.

Table 3-19. Facility environments*.

Location	Temperature, °F (K)	Humidity, %	Clean room, class†
Hangar S			
Clean rooms	72 ± 3 (295 ± 1.7)	45 ± 5	100 000
Systems test area	76 ± 3 (297.6 ± 1.7)	50 ± 5	
Hangar AO			
High bay	75 ± 2 (297 ± 1.1)	45 ± 5	100 000
Hangar AE			
Clean room	72 ± 3 (295 ± 1.7)	45 ± 5	10 000
Hangar AM			
High bay	75 ± 3 (297 ± 1.7)	45 ± 5	
Clean room	75 ± 5 (297 ± 3)	40 (max.)	10 000
Explosive safe area 60A			
Spacecraft Assembly Bldg	73 to 95 ± 3 (296 to 308 ± 1.7)	50 ± 5	100 000
Propellant lab	73 ± 3 (296 ± 1.7)	50 ± 5	100 000
Instrument lab	76 ± 3 (297.6 ± 1.7)	50 ± 5	
Delta Spin Test Bldg	75 ± 5 (297 ± 2.8)	50 ± 5	
Operations & Checkout Bldg	75 ± 3 (297 ± 1.7)	45 ± 5	100 000
SAEF-1			
Airlock and high bay	70 ± 5 (294 ± 2.8)	45 ± 5	5 000 (inlet)
SAEF-2			
Airlock, high and low bay	75 ± 3 (297 ± 1.7)	45 ± 5	100 000
VAB	Not controlled	Not controlled	Not controlled
Orbiter Processing Facility			
High bay	75 ± 3 (297 ± 1.7)	50 (max.)	100 000 (inlet)
Cargo bay enclosure	70 ± 5 (294 ± 2.8)	50 (max.)	5 000 (inlet)
Launch pad	Not controlled	Not controlled	Not controlled
Payload changeout room	70 ± 5 (294 ± 2.8)	30 to 50	5 000 (inlet)

*All figures represent design specifications; in some facilities, actual conditions could vary because of ambient conditions and the nature of the operations being conducted.

†Federal Standard 209B, April 24, 1974, Clean Room and Work Station Requirements for Controlled Environments.

The base of the standard container is of steel construction and the floor is insulated with polyurethane. The insulated cover is 2 inches (5 centimeters) thick. The outside surfaces are sheet aluminum and the inside surfaces are fiberglass. An interface feedthrough panel provides payload services as required. Two sides have 3- by 4-foot (0.91- by 1.22-meter) access doors. Lights and reflectors on the outside meet Interstate Commerce Commission regulations for highway movement.

Table 3-20. Payload/standard transportation system interfaces.

Type and purpose	Interface
Mechanical or structural	
Structural mount	Payload adapter
Shock insolation	Payload adapter Carrier air-ride system
Electrical	Auxiliary power unit (28 V dc; 115 V ac, 50/60 Hz)
Environmental	
Temperature	Environmental control system
Relative humidity	Environmental control system
Cleanliness	Static-free bag
Protection	Hard container
Instrumentation and data recording	Accelerometers Thermometer Humidity sensor Power-level sensor Alarm system

The container has its own environmental control system (ECS), which requires 208 volts ac, three-phase 50/60 hertz to operate. The power is provided by the auxiliary power unit (APU) or from facility power sources. A positive-pressure filtered air purge is maintained to the container during transit. A battery is included that could supply power to the payload and operate the transport environment monitoring system for at least 4 hours if the generator were to become inoperable.

(b) Payload-Handling Equipment. Those items in the basic hardware inventory for payload handling that will be needed by most users include payload canisters, canister transporters, and payload-handling fixtures (strongbacks).

The strongback (Figure 3-40), is a rigid-frame device consisting of beams, cables, attachment hook devices, and rings. It is adjustable to accommodate varying lengths and shifting centers of gravity of payloads up to the maximum for an Orbiter payload. The strongback will interface with the payload so that it will not interfere with engagement and load transference to attachment/retention points. It will not induce any bending or twisting loads on any payload element.

The canister, Figure 3-41, is equal in size and configuration to the Orbiter cargo bay, including similar doors on the top. In addition, one end is hinged to allow vertical payload installation. Service panels, tie-downs, and lift points are also part of the canister to allow rotation of the container. Special platforms for personnel access to the open canister can also be used. This equipment consists of a bridge-type structure that spans the canister and walkways along each side of it. The bridge can be raised or lowered; at maximum elevation it clears the payload envelope.

The transporter is capable of moving a fully loaded canister. Its suspension system helps to minimize shock and vibration.

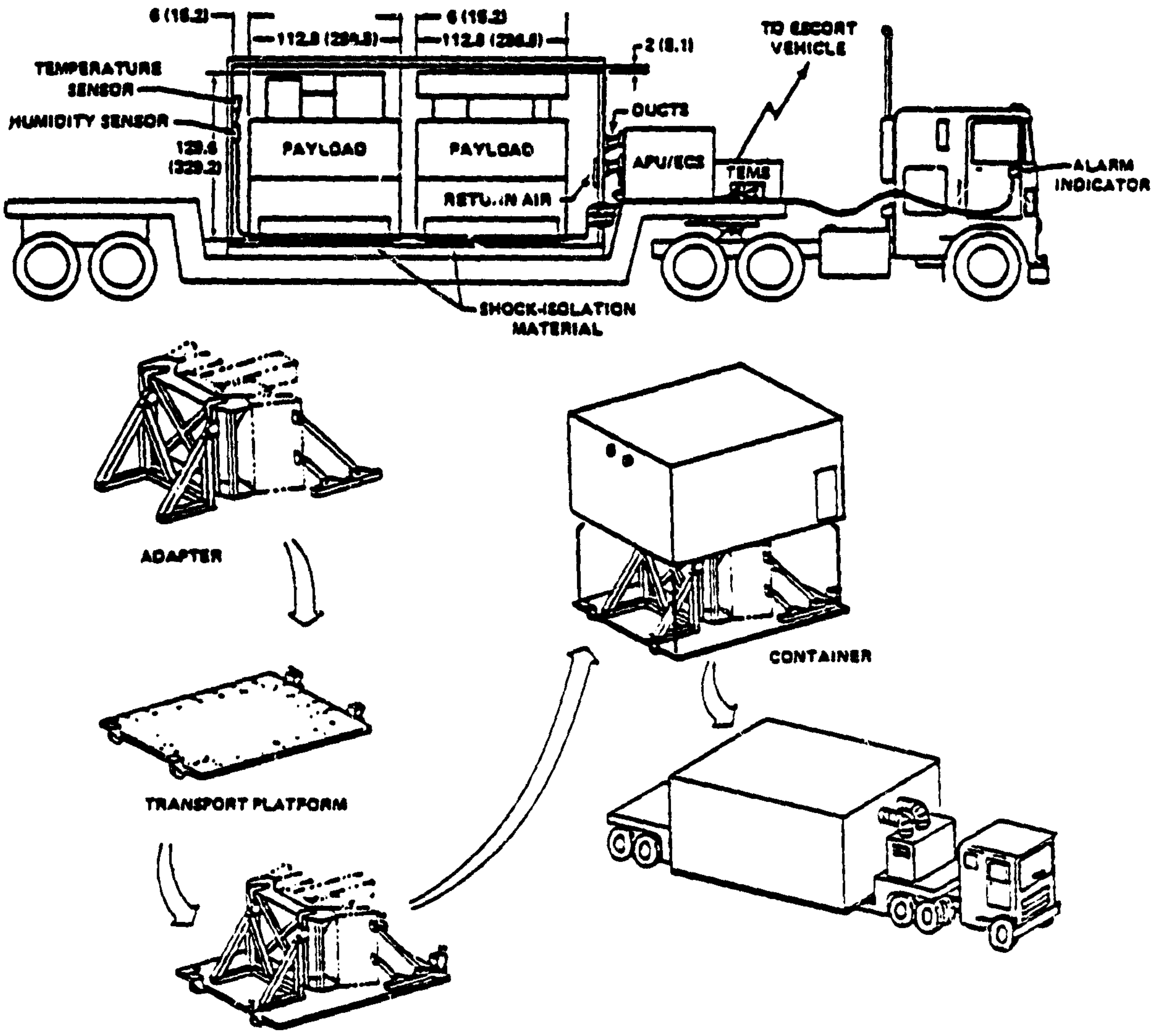


Figure 3-39. Standard transportation system elements.

(c) Cargo Integration Test Equipment. Cargo integration test equipment (CITE) has the capability to verify interfaces off-line, including payload-to-payload and cargo-to-Orbiter mechanical and functional interfaces.

The CITE in the Operations and Checkout Building can accommodate horizontally processed cargoes. See Figure 3-42. Vertical processing is done by the CITE in SAEF-1.

Included in this equipment are structural assembly stands, mechanical clearance and fit gauges, electrical wiring, thermal-conditioning items, electronic test sets, and radio-frequency transmission equipment adapters.

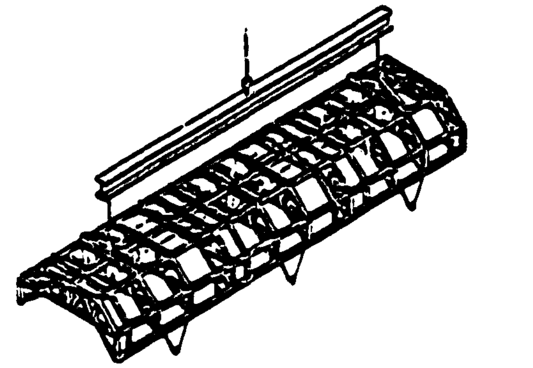


Figure 3-40. Horizontal handling fixture (strongback) for payloads.

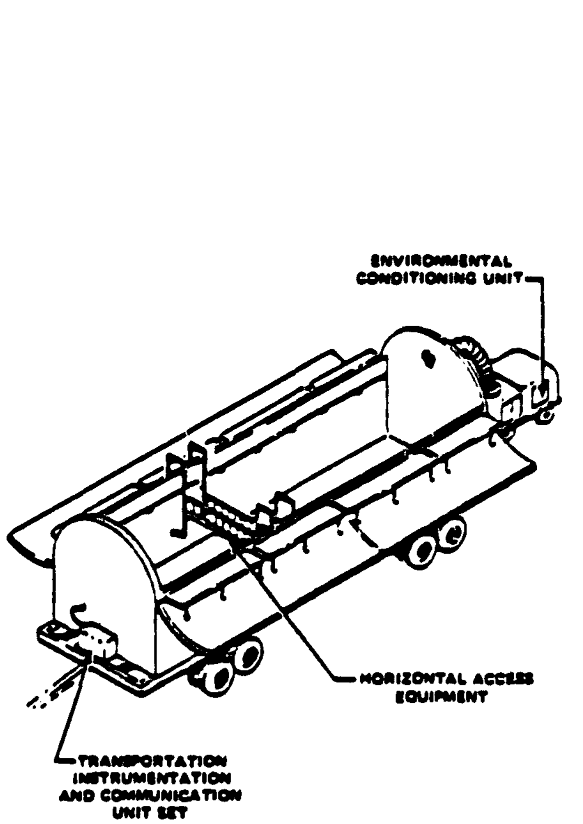


Figure 3-41. Payload canister shown mounted on its transporter.

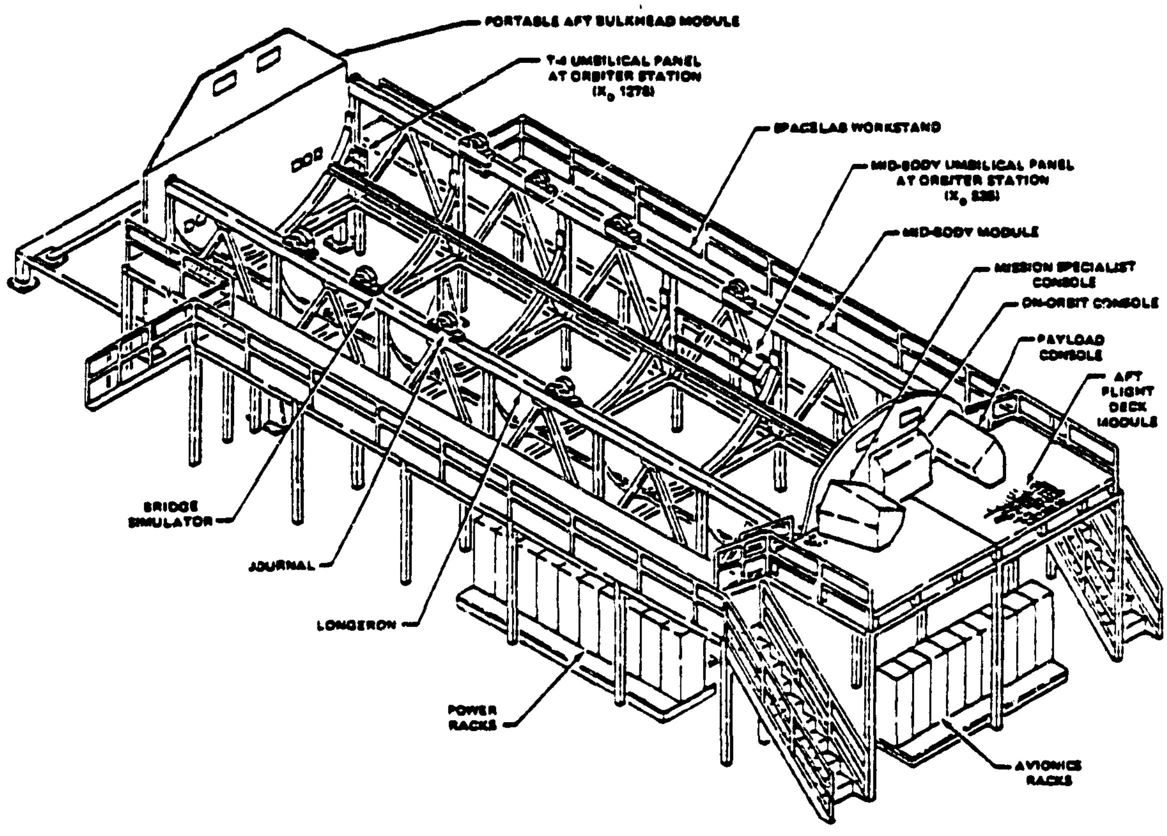


Figure 3-42. Layout of cargo integration test equipment for horizontal cargo.

The CITE satisfies the STS requirement to perform final assembly and integrated testing of cargo before it is mated to the Shuttle. It may also be used to satisfy the payload interface verification requirements.

(U.H.) 5. Interfaces. Standard payload interfaces and services required at the launch site will be made available to all users but the users will retain primary responsibility for performance and off-line processing of their payloads. To fulfill this host concept, the launch site staff must schedule and integrate facilities, support equipment, services, and personnel. The user involvement is shown in Figure 3-43.

Planning launch site support for payloads will begin with initial contact between the user and the designated launch site support manager. The LSSM will be assigned early in the program and will become the user's "host." He will become acquainted with the user's organization and will work with that organization in defining launch site capabilities and planning launch site operations. Initial emphasis will be on long-lead items, conditions that might affect payload design, and resolution of problems that pose potential difficulties. Any new capabilities required must be evaluated for cost and schedule effects. Even if payload processing requirements are incomplete, they should be submitted at the earliest possible date to allow ample time for evaluation, planning, and integration into the STS processing.

(U.H.) 6. Responsibilities. During planning, the user, using the KSC Launch Site Accommodations Handbook, has the responsibility to:

- Establish specific processing flow requirements.
- Identify facility services required.
- Identify payload-supplied support equipment required for use at the launch/landing site.
- Identify activation/deactivation requirements associated with unique support equipment.
- Ensure reliability and quality assurance during the off-line processing in support of payload readiness.
- Prepare procedures for accomplishing processing before STS mating.
- Input to and review integrated procedures for on-line testing with the STS.
- Perform safety assessment.
- Identify test support requirements for payload involvement in integrated operations.
- Provide certification of payload readiness.
- Place a security designation, if applicable, on all material submitted.
- Identify and budget for payload costs to be incurred at the launch site.

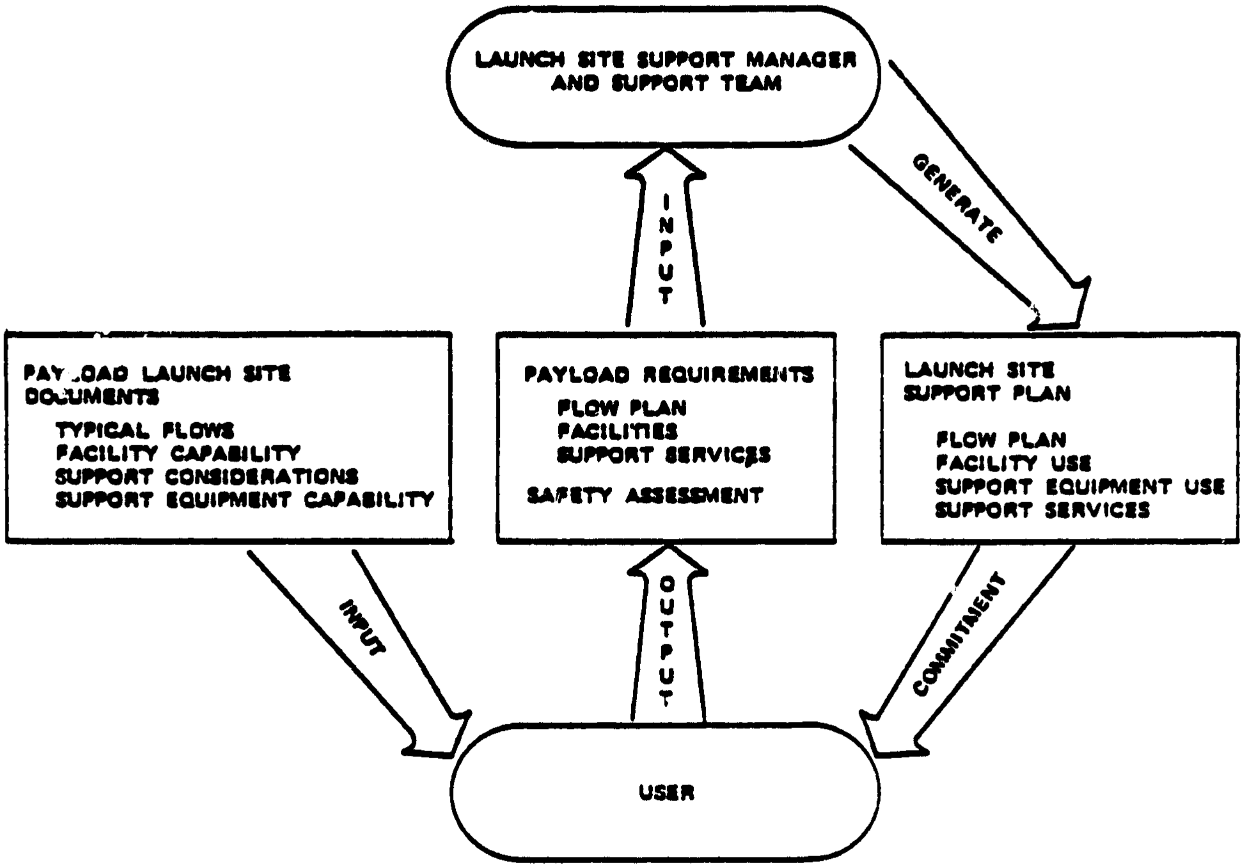


Figure 3-43. User involvement in launch site operations planning.

The launch site organization will be responsible for providing assistance to the user in planning integration and checkout of the payload elements with the STS, planning and scheduling facility use and payload flow, ensuring that all payload requirements are met, and conducting the launch operations. Users must provide sufficient documentation to define all requirements for their payloads at the launch site.

For complex payloads (particularly those requiring major construction of facilities at the launch site), planning should begin several years before the payload is scheduled to arrive at the launch site. Most payloads, however, will require significantly shorter lead times.

The user will retain prime responsibility for off-line operations involving only his hardware. Once integration with other payloads or STS hardware begins, the launch site will assume overall responsibility but will require detailed inputs and data review from the user. Users will retain performance responsibility for their payload and will remain involved through the entire on-line flow as well.

(U.H.) 7. <u>Services.</u> In addition to the equipment, both technical and administrative support services are available to fit the needs of users. Administrative support includes office space, communications and transportation facilities, equipment, and tools. Technical support for payload processing includes clean rooms, test equipment, propellants, ordnance testing and storage, chemical analysis, shops, and laboratories.

Complete technical services are available to satisfy legitimate requirements of users. However, these are not intended to supplement work that should have been performed in the user's home plant. If inactive support services must be reactivated for a user, negotiated cost and schedules must be considered.

(U.H.) c. <u>Mission Support.</u> During all on-orbit periods when a payload has an operational interface with the Space Transportation System, flight operations support will be provided jointly by the Mission Control Center (MCC) and by the Payload Operations Control Center (POCC) responsible for that payload. The MCC will provide total support for other phases of the flight — prelaunch, ascent, reentry, and landing.

1. <u>Mission Control Center.</u> The MCC is located at the Lyndon B. Johnson Space Center (JSC), which has been designated as the STS operator for all NASA flights. Flight operations command and control facilities are located in the MCC.

For all flights, the MCC provides systems monitoring and contingency support for all STS elements, provides two-way communications interface with the crew and onboard systems, performs flight data collection to a central site, and provides a preflight and inflight operational interface with the POCC to coordinate flight operations.

The STS operations organization within the MCC consists of three major elements or functions: a planning operations management team (POMT), multipurpose support groups, and small flight control teams.

The POMT serves primarily to perform a preflight (approximately 2 years to 16 weeks before launch) function, with management responsibility for the detailed development, planning, scheduling, and status of all STS flights. The POMT will provide assistance to the user in preparing requirements documentation for facilities, software, command, telemetry, flight requirements, and POCC interfaces.

The multipurpose support function includes the bulk of STS flight planning, procedures development, and systems expertise and manpower. The multipurpose support teams provide direct support for preflight planning and training activities and, during the flight, provide systems and trajectory statusing support to the flight control room on a routine and periodic basis.

The flight control team is the only flight-dedicated element in the operations concept; these people are on duty 24 hours a day for the duration of each STS flight. They provide direct real-time flight support to the crew through flight monitoring and assistance during launch and entry, and by following the flight activities during the orbital phase. The real-time planning and execution of payload operations activities will be primarily the responsibility of the POCC.

2. Payload Operations Control Center. The POCC has the computation and display capability necessary to provide data for operational control of payloads as well as the capabilities for payload communications and command. (See Table 3-21.)

   Generally, the same data that are available to the STS controllers within the Mission Control Center are also available to the user in the POCC. The POCC also provides similar capability to the MCC for command uplink and voice communications both with the onboard crew and with flight controllers in the MCC. Table 3-21 provides a summary of the standard capabilities in the JSC POCC for data monitoring, command and control, accommodations, and services.

   Interfaces between the POCC and the MCC are simplified somewhat by the fact that both are located in the same building (Building 30, Mission Control Center complex at JSC). Payload operations for attached payloads require close coordination between the POCC and the MCC throughout the duration of a flight. No handoff is made, as it is to the other two POCCs when their spacecr't get out of range of the Orbiter.

   The responsibility for managing and staffing the JSC POCC lies with the user; thus, the organizational structure is flexible and may vary somewhat from flight to flight. However, the user is expected to designate an individual within the POCC who has overall responsibility for all payload operations decisions.

3. Payload Control. All commanding through the Orbiter to payloads will be under the direct control of the MCC and will pass through or be initiated at the MCC. As much as 2 kilobits/sec of command data (various types, formats, and bit rates) can be transmitted to payloads through the Orbiter. The intent of the Shuttle command system (onboard and ground system) is to provide for maximum transparency to payload commands, while retaining adequate control for crew safety. Some specialized preflight planning with the user is necessary to achieve this goal. The following command system features and operations concepts are used.

Table 3-21. JSC POCC standard capabilities.

Facility	• Consoles, desks, chairs, tables, recorders, telephones, headsets for voice monitoring
Voice communications	• Voice loops (both internal and external to JSC) for coordinating STS/payload flight planning activities • Two-way voice communications with crew during flight • Voice transcripts and/or voice tapes of crew conversations
Command data (uplink)	• Commands can be generated from an assigned console position in the POCC • Some training will be provided so that the user will be familiar with command generation procedures • Command histories can be retrieved from real-time processors and displayed on the console. Command histories may also be obtained from off-line processors (printouts or tapes)
Telemetry data (downlink)	• Real-time monitoring of the STS systems data (same capability as MCC controllers) • Real-time processing and display of payload command and control data • Real-time processing and display of science data (≤1 Mbit/sec) contained in independent science downlinks • Near-real-time processing and display of science data contained in independent science downlinks (the data rate is limited to ≤1 Mbit/sec and subject to change)
Special processing	• Special computations for real-time and near-real-time displays • Analysis program support (the amount of support will be negotiated on a case-by-case basis)
Trajectory	• All ongoing trajectory and Orbiter attitude information will be made available to users as required • Orbit phase processing of trajectory will be performed as required to support payload operations
Output devices	• Digital television equipment displays • Strip chart recorders • Tabular reports • Science data tapes generated at a remote site • Standard computer-compatible tapes containing STS systems and trajectory data
Video downlink	• Can monitor in real time all video downlink • Video tapes available post flight
Natural environment support	• Worldwide meteorological data • Space environment data (reports on solar activities, energetic particles, artifical events, geomagnetic activity, auroral data, and ionospheric disturbances)

An STS/payload command plan will be developed and jointly agreed upon by JSC and the user, with particular attention given to the countdown, launch, insertion, and payload-activation sequences. To ensure Orbiter safety and to allow for interruption of normal, preplanned POCC command sequences during Orbiter contingencies, the MCC will maintain the capability to enable/disable POCC command output through the MCC.

A list of payload commands that constitute a hazard to the Orbiter (while the payload is attached to or near the Orbiter) will be identified jointly by JSC and the user during preflight planning. The user may add to the list any commands considered hazardous to the payload itself. This joint command list will be entered into the MCC command software (safed).

A definite handover time for detached payload operations will be established jointly by JSC and the user before the flight. The plan will define the point after which POCC commands will cease to pass through the MCC and will be initiated and routed independent of STS commands. In establishing the proper handover time, the primary consideration is to maintain Orbiter and crew safety after the handover of command respon·ibility.

3.7 REQUIREMENTS FOR PROGRAM ELEMENTS

3.7.1 FLIGHT HARDWARE. Flight hardware shall conform to the applicable performance requirements of Section 3.2 and the design and construction standard specified in Section 3.3.

3.7.1.1 Airborne Support Equipment (ASE). ASE shall be returned from low earth orbit by the STS following completion of all Shuttle supported construction, installation, and test operations.

a. Beam Builder Functional and Design Requirements. The beam builder shall automatically fabricate a triangular-cross-section truss from preprocessed graphite/glass/thermoplastic strip material. The beam builder shall provide the operations and equipment necessary to assemble truss elements (e.g., crossmembers to cap sections) and cut the truss to required length. (PROP.)

   1. Beam Builder System Requirements.

      (a) Beam Configuration. The beam produced by the beam builder shall conform to the dimensions shown in Figure 3-1. The system shall control the accuracy of the finished beam to meet the following requir .ents: (DER)

         (1) Bay length tolerance: ±0.381 mm

         (2) Straightness of the beam shall be controlled to an average error of ±0.1 mm/m for a theoretically unloaded beam in zero gravity.

(3) Beam torsional deflection created by internally induced loads only shall be limited to ±0.006°/m.

(DER) (b) Dimensions. The overall envelope for the basic beam builder system shall conform to Figure 3-44.

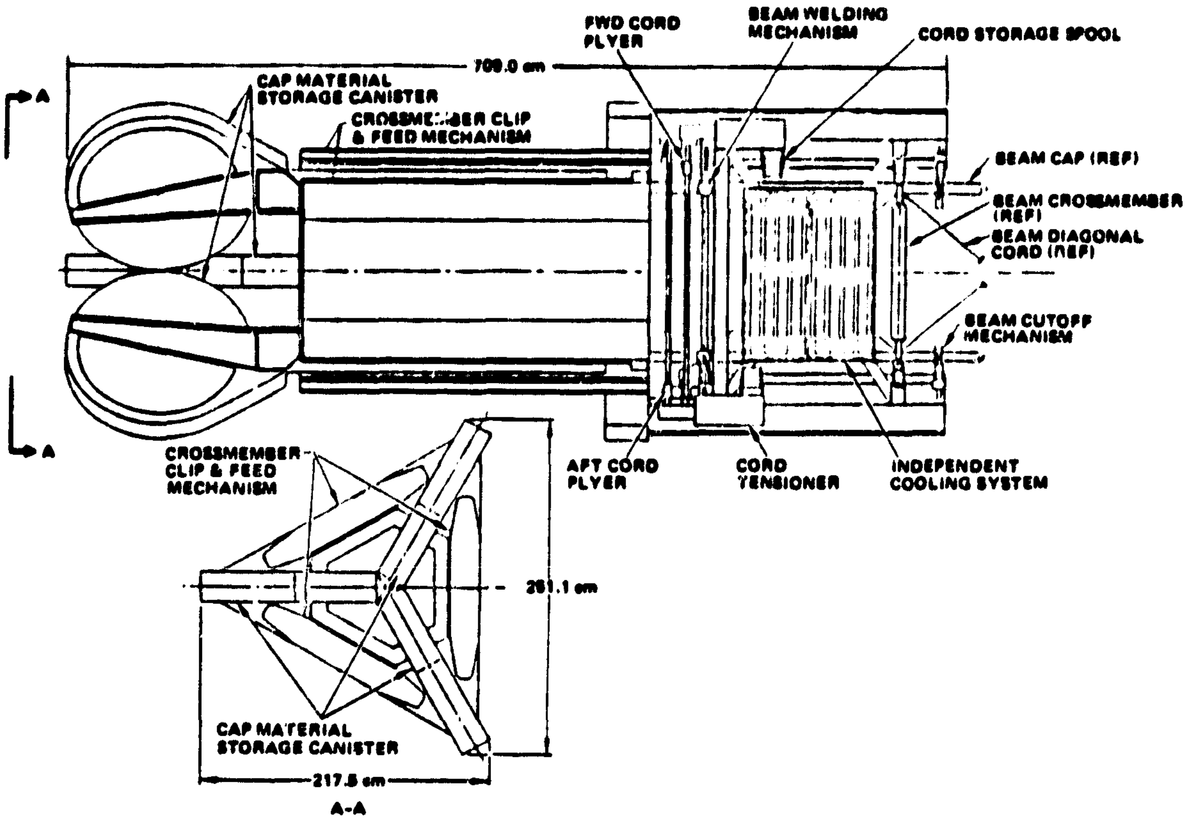


Figure 3-44. Beam builder envelope dimensions.

(DER) (c) Weight. Total weight of the beam builder, including a full load of material and all flight auxiliary subsystems (heat rejection subsystem, thermal shroud, and latch and deployment mechanisms) shall not exceed 3404 kg (7,499 lb).

(DER) (d) Performance. The beam building process shall produce the completed beam in accordance with the mission timeline allocation at an average speed of 1.79×10^{-2} m/sec. Power and energy required for beam fabrication shall not exceed the levels specified in Table 3-22. Timing and synchronization of fabrication operations shall generally conform to the timeline shown in Figure 3-45 for normal bay production and to Figure 3-46 for a cutoff bay sequence.

Table 3-22. Baseline beam builder power & energy requirements

Process/Bay	Energy (KJ/Bay)	Avg Pwr (W)	Peak Power (W)	Energy
Cap Heating/Forming	105.4	1318.	1215 205 1420	66%
Cooling	4.6	58.	58	3%
Welding	21.6	270.	900	13%
Subsystem Assembly & Control	28.9	362.	861	18%
Totals/Bay	160.5	2008.	3239	100%

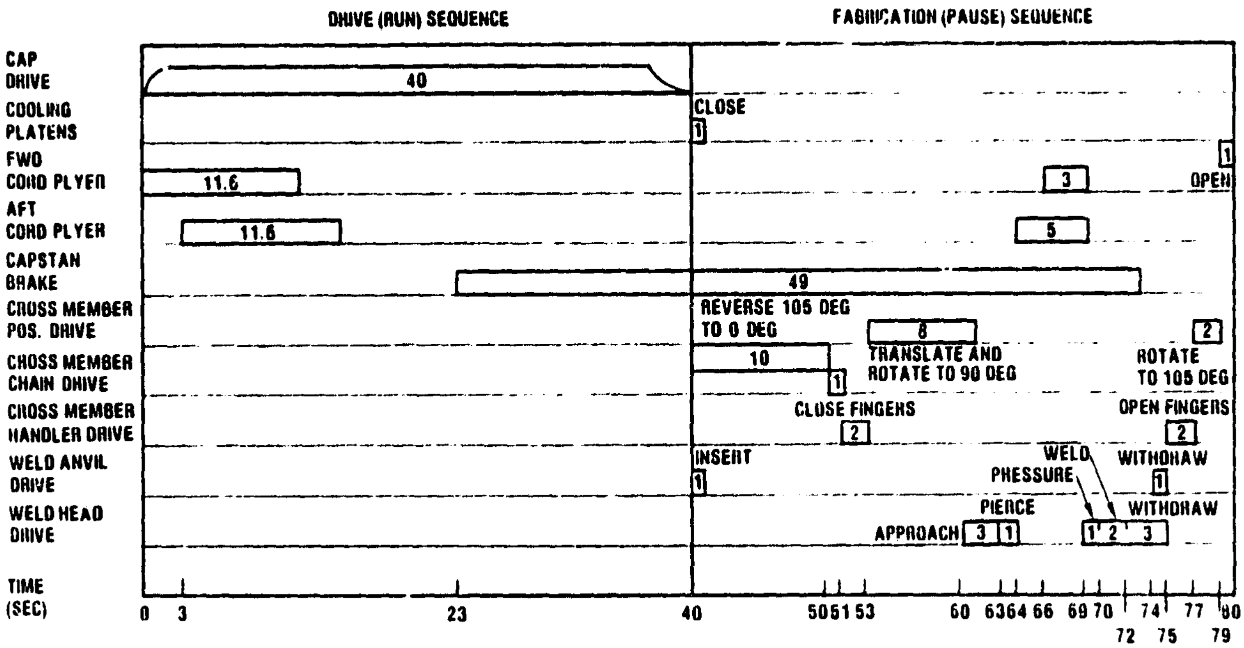


Figure 3-45. Normal bay timing and synchronization.

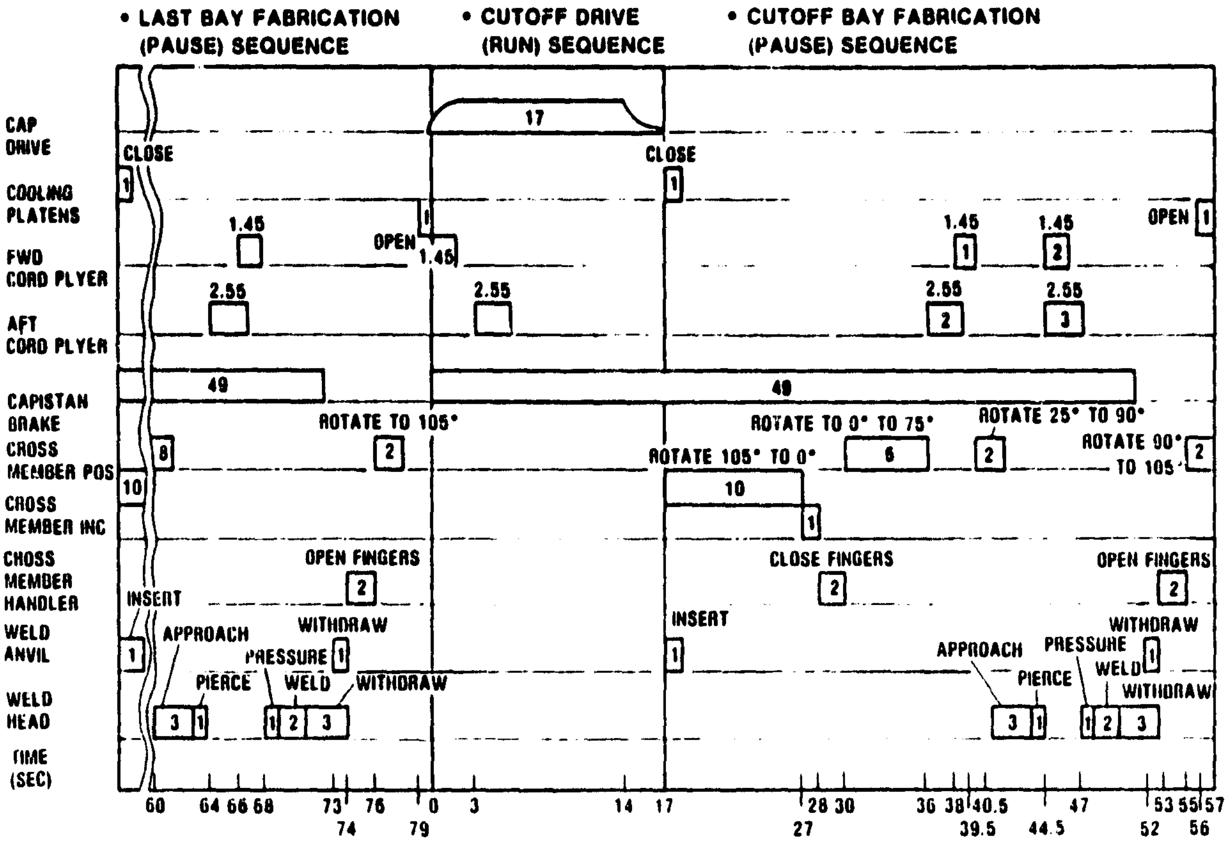


Figure 3-46. Cutoff bay timing and synchronization.

(DER)

(e) Safety and Reliability. General requirements for achieving optimum safety and reliability for the flight article are outlined as follows:

(1) Redundant system elements shall be provided as follows:

- Wherever the failure of a system element will result in damage to the beam or beam builder equipment if the failed element is not backed up by a redundant element or redundant operating mode.
- Wherever the manual replacement of a failed system element in space is either not feasible or would require so much time and effort that the mission objectives cannot be achieved.
- Wherever the failure of a system element compromises Orbiter or flight crew safety during any mission phase.

(2) Condition monitoring and fault detection (CMFD) provisions shall be incorporated as follows:

- The failure of any critical system element which will cause damage to the beam or beam builder equipment shall be detected automatically.
- The control subsystem shall diagnose the failure and initiate corrective action before damage occurs. The control subsystem shall either stop the beam builder process in a safe mode or allow the process to continue uninterrupted by automatic switch-over to a redundant element.

(f) Subsystems. The integrated beam builder system shall include the following subsystems, which shall be modular to the maximum extent practicable.

(1) Cap Forming Subsystem
(2) Joining Subsystem
(3) Crossmember Subsystem
(4) Cord Subsystem
(5) Cutoff Subsystem
(6) Controls Subsystem
(7) Structure

(g) STS Interfaces. The beam builder hardware, which interfaces with the STS, shall be compatible with the STS interfaces specified in Subsection 3.6.1. (DER)

2. Cap Forming Subsystem Requirements. The cap forming subsystem shall include the processes and controls necessary to form rolled flat strips of graphite/glass/thermoplastic material into the required shape for the baseline beam caps while driving the finished caps into the assembly processes and beyond. The subsystem shall consist of three cap forming machines, each having processes to store, heat, form, cool, and drive the material per the following requirements and as specified in Table 3-23.

(a) Storage Section. The storage section shall store and feed the flat strip stock material and prevent unwinding of the material during all phases of operation. (IRAD, I

(b) Heating Section. The heating section shall heat and control the temperature of the material before it enters the forming section. It shall be equipped with necessary guides to provide smooth low friction flow of material from the storage section to the forming section. The heating section shall be designed to operate in both air and vacuum. (IRAD, I

(1) Heat shall be concentrated on the bend zones of the material. Heaters shall raise the temperature of each bend zone from its prevailing input temperature 294 K min to the required temperature of 492 ± 14 K.

(2) The heating section heaters shall be thermally insulated to limit heat loss to TBD Btu/hr maximum during stabilized operation cycling.

(3) Power overload devices shall shut down the heaters and the process in the event of a malfunction.

(4) Heater controls shall modulate power to the heaters as a function of material temperature set point. Heaters along each fold line shall be controlled to prevent temperature overshoot during heat-up operation and to maintain a steady set point temperature during standby operations.

Table 3-23. Cap forming subsystem requirements.

PROCESS	PARAMETER	LIMITS OR TOLERANCE
Strip Material Storage Roll	O.D.	121.4 cm Max
	I.D.	30.5 cm Min
	Length	905 m (at launch)
	Width	19.05 cm
	Weight	792 kg (at launch)
Strip Material Heating	Temperature Control Limits:	
	1st Stage	450 ± 14 K
	2nd Stage	492 ± 14 K
	Forming Section	492 ± 14 K
	Max. Start-Up Time in Vacuum	430 seconds
Forming	Max. Forming Rate	TBD cm/sec
Cooling	Platen Actuation Time (open or close)	1.0 ± 0.3 seconds
	Max. Cooling Time	12 seconds
	Max. Material Use Temperature	394 K
	Coolant Supply Temperature	TBD K
	Coolant Flow Rate	TBD kg/sec
Drive	Max. Cap Speed	3.81 cm/sec
	Max. Acceleration	3.0 cm/sec^2
	Max. Force Capability	804 N
	Max. Force Required	640 N
	Run Time	40 seconds
	Pause Time	40 seconds

(c) Forming Section. The forming section shall form the cap member to the required cross section configuration shown in Figure 3-1. Heaters within the forming section shall heat the material bend zones for system start-up. The heaters will also maintain material temperatures along each bend zone during system operation in air. (IRAD, I

(d) Cooling Section. The cooling section shall cool the formed cap member below the maximum use temperature prior to entering the drive section. All coolant circulation equipment, e.g., pumps, reservoirs, regulators, radiator, etc., shall be provided by an independent heat rejection subsystem. (IRAD, I

(e) Drive Section. The drive section shall provide the pull force on the material necessary to move the material from the storage roll through the heating, forming, and cooling processes. It shall push the finished beam caps through the assembly processes and deploy the finished beam. During the run cycle, the cap drive sections shall be controlled to provide a uniform displacement of all three cap members within ±0.25 cm of each other at the nominal displacement and rate characteristics shown in Figure 3-47 under the maximum total load requirement shown in Figure 3-48. (IRAD, I

3. Crossmember Subsystem Requirements. The crossmember subsystem shall include the mechanisms, drives, and controls necessary to store, feed, and position prefabricated crossmembers used in the construction of the beam. The (DER)

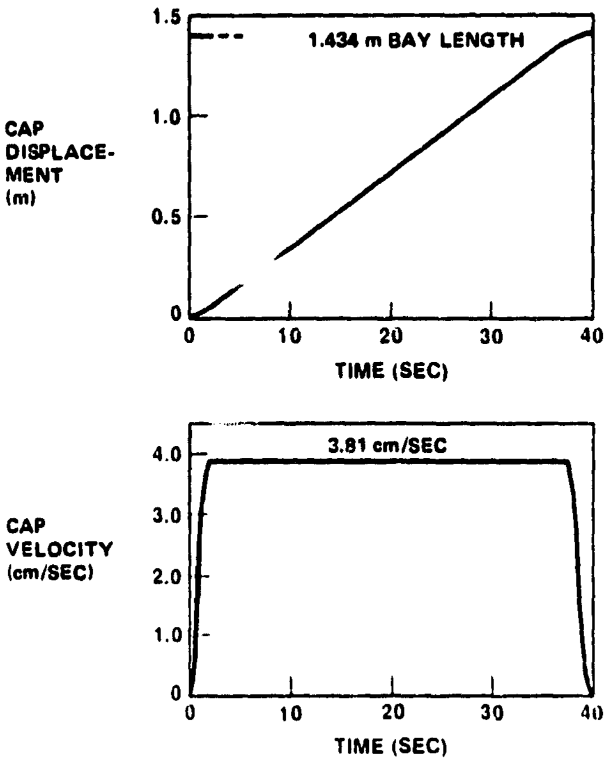


Figure 3-47. Cap drive section displacement and rate requirements.

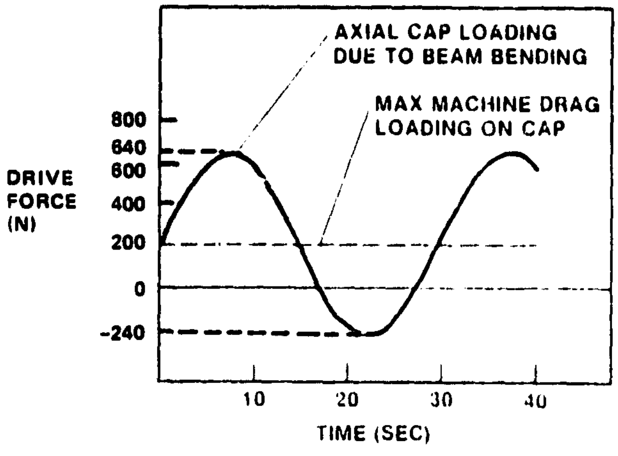


Figure 3-48. Cap drive maximum load requirement.

crossmember shall be 130.80 cm in length with a cross-section as shown in Figure 3-1. The crossmember subsystem shall consist of three storage and feed clips powered by a single feed drive unit, and a handler/positioner mechanism as shown in Figure 3-49.

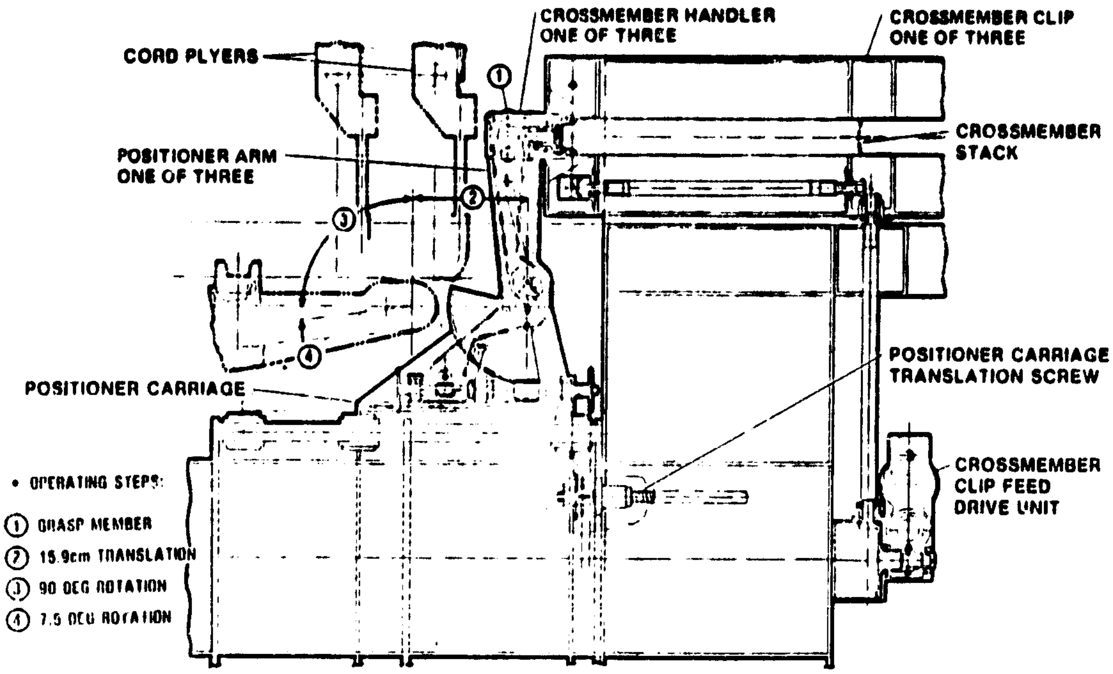


Figure 3-49. Crossmember Subsystem modules.

DER)

(a) Crossmember Storage and Feed Modules. The storage and feed clips shall each be capable of storing 650 crossmembers. The clip feed mechanism shall eject only one crossmember per feed cycle while maintaining positive retention of all remaining crossmembers in the clip. The feed drive module shall drive all three clip feed mechanisms simultaneously to eject one set of three crossmembers in 1 second max.

DER)

(b) Crossmember Handler/Positioner Module. The handler/positioner shall accept and grasp three crossmembers as they are ejected from the storage and feed clips, then translate and rotate them into position for joining them to the beam caps. After joining is complete, the handlers shall release the crossmembers and be rotated clear of them to allow the beam to advance without interference. After the cord plyers have been cycled to the next position, and beam motion is stopped, the handler/positioner is returned to the position for receipt of the next crossmembers from the feed clips. Maximum time allocated for these functions shall be as indicated in Figures 3-45 and 3-46.

4. Cord Subsystem Requirements. The cord subsystem shall include the mechanisms, drives, and controls necessary to store, feed, position, and tension the six beam diagonal cord members. The cord subsystem shall consist of six storage and feed spools, six cord tensioner mechanisms, and six cord plyers. The cord subsystem operating sequence shall be in accordance with Figure 3-50. (DER)

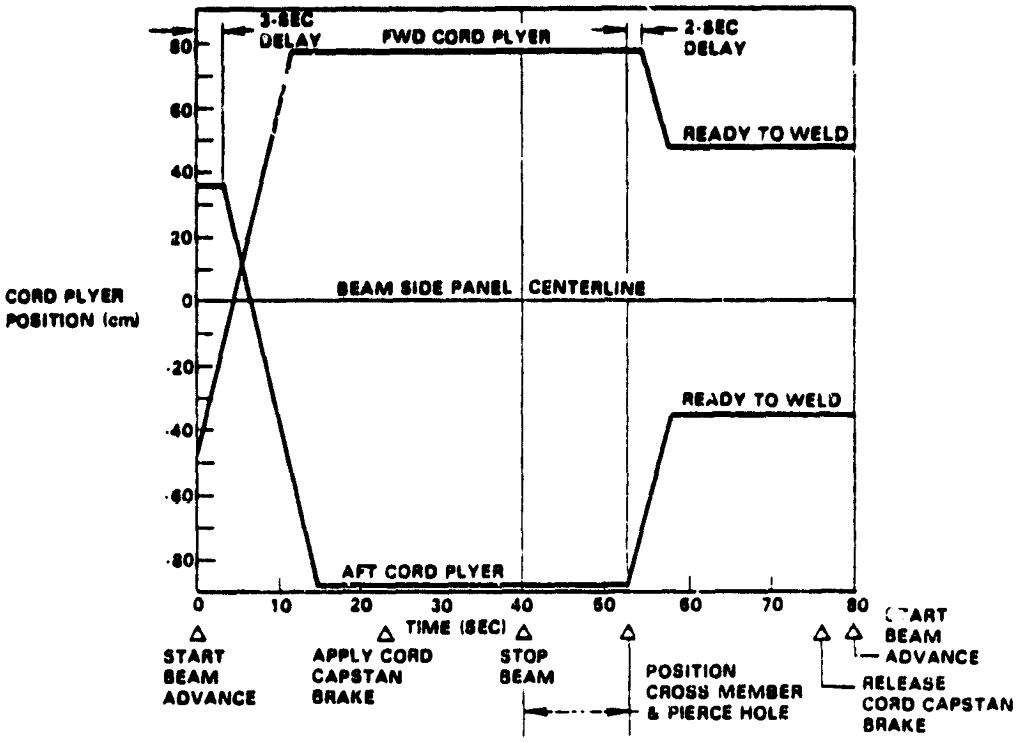


Figure 3-50. Cord subsystem operating sequence.

(a) Cord Storage and Feed Modules. Each cord storage and feed module shall consist of a storage spool, a storage spool shaft drag brake, and a mounting support. Spool and drag brake requirements are as specified in Table 3-24. The spool shall be wound with cord in such a way as to prevent tangling or twisting as the cord is unwound. The drag brake shall prevent overtravel or backlash of the spool when cord feed is suddenly stopped. (DER)

(b) Cord Tensioner Modules. The cord tensioner module shall include: a free-turning capstan, with an electrically energized brake for stopping cord feed; a constant force spring with operating characteristics as specified in Table 3-24, for applying the tension load to the cord; a load cell for measuring applied cord tension; and the necessary pulley mechanisms for routing and tensioning the cord as it passes through the tensioner module. (DER)

Table 3-24. Cord subsystem requirements.

PROCESS	PARAMETER	LIMIT OR TOLERANCE
Cord Storage	Cord on Spool:	
	Length	1219 m
	O. D.	13.12 cm
	I. D.	7.62 cm
	Width	13.12 cm
	Weight per Spool	2.13 kg
	Spool Drag Torque	56.5 ±5.6 N-cm
	Max. Cord Speed	10.1 cm/sec
Cord Tensioner	Tensioning Force	44.5 ± 8.9 N
	Spring Stroke	21.2 cm
	Spring Load Rating	89 N
	Pulley Diameter	7.1 cm
Cord Plyer	Travel Speed	9.3 cm/sec
	Pulley Diameter	7.1 cm
	Total Stroke:	
	Forward Plyer	149.40 cm
	Aft Plyer	172.80 cm

(DER) (c) Cord Plyer Modules. Forward and aft cord plyer modules shall be identical, except for stroke, as specified in Table 3-24. Two types of cord plyer modules shall be provided. One of the cord plyer modules in the forward and aft sections shall be motor driven. The remaining two cord plyer modules in each section shall be slaved to the driven module by flexible drive shafts at each end. The slave modules shall be equipped with a rotary shaft encoder for sensing cord plyer position as a function of the number of turns of the lead screw. The lead screw shall be a reciprocating style which drives a low friction ball nut from end-to-end with one way rotation of the shaft.

(DER) 5. Joining Subsystem Requirements. The joining subsystem shall ultrasonically weld the crossmembers and capture the diagonal cord members between the mating surfaces of the cap and crossmember as shown in Figure 3-51. The joining subsystem shall consist of six ultrasonic welders with associated welder controllers, welder positioning mechanisms, process control sensors, and one anvil drive mechanism.

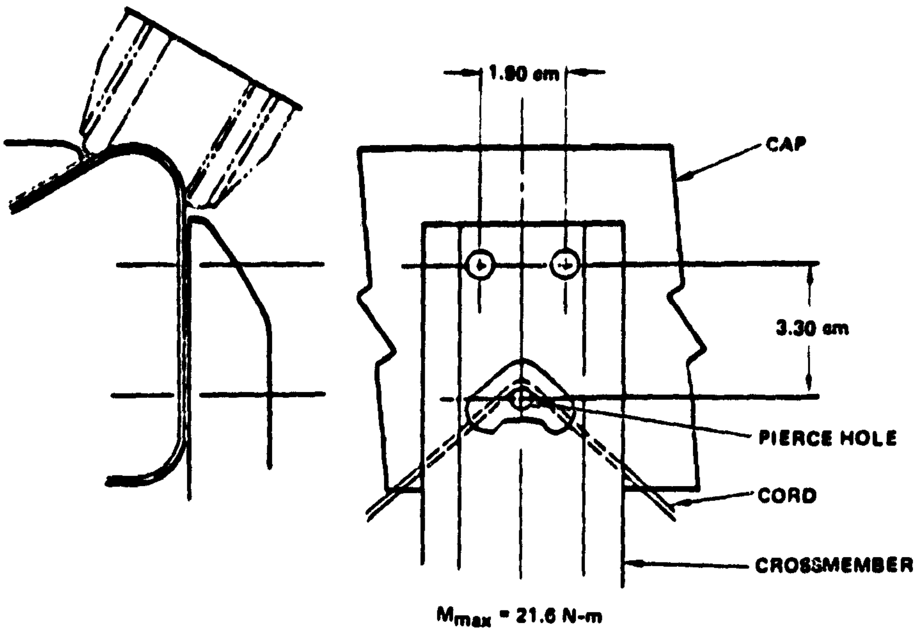


Figure 3-51. Beam joining requirements.

Each welder shall have a weld horn with three integral weld tips and a piercing pin. The welding sequence shall conform to the allocated time limits established in Figures 3-45 and 3-46. The welding sequence shall be performed as shown in Figure 3-52. The weld process controls shall provide 100% verification of weld quality. The piercing and welding process shall produce no debris or outgassing of the thermoplastic resin.

6. Cutoff Subsystem Requirements. The cutoff subsystem consists of three cap cutter modules. All three cap cutters shall be operated after a cutoff bay sequence (Figure 3-46), followed by one normal bay sequence, to sever the finished length of beam from the beam builder. The cap cutter shall shear the cap squarely and cleanly leaving no debris or frayed ends in the sheared edges of the cap. The maximum time allocated to engage and shear the caps is 3 seconds. Maximum time allowed for retraction of the cutters is also 3 seconds. (DER)

7. Heat Rejection Subsystem Requirements. The heat rejection subsystem shall circulate liquid cooling fluid through the three cap forming machines for removal of waste heat from the cooling platens and heater reflectors. The closed coolant fluid loop shall circulate the fluid from the cap forming machines through a radiator panel for rejection of the waste heat to space. The heat rejection subsystem shall consist of a radiator panel, a circulating and control module, and the interconnecting plumbing. The radiator shall be designed to reject a 450-watt total cooling load under maximum solar (DER)

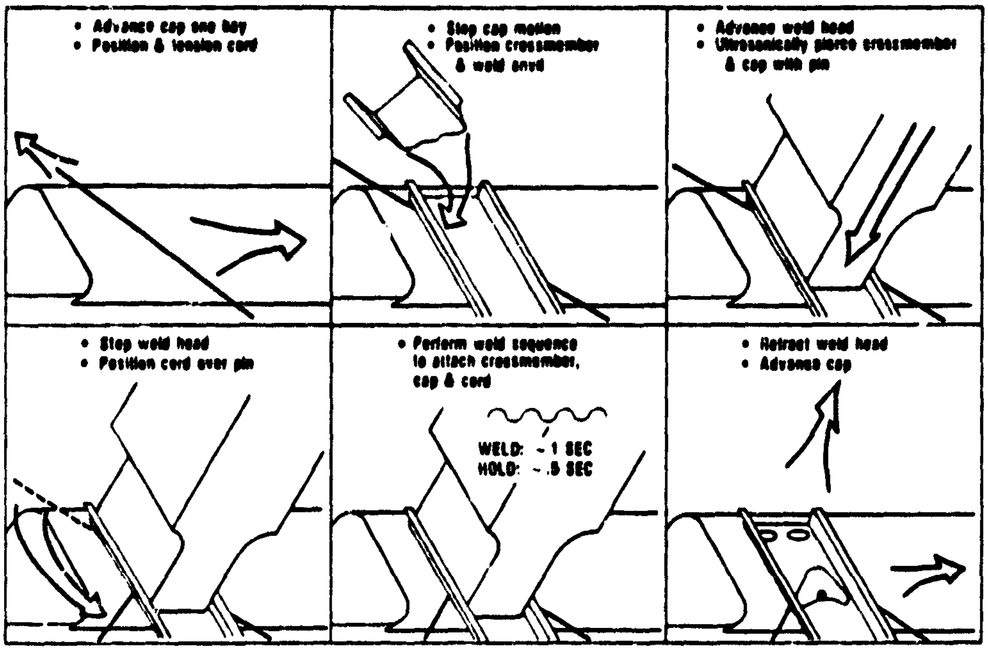


Figure 3-52. Beam assembly welding sequence.

heat influx conditions. The circulating and control module shall contain the necessary pumps, filters, accumulators, and fluid servicing ports required to control pressure, maintain fluid flow, maintain cleanliness of the circulating fluid, and permit fill and drain of the cooling fluid for system maintenance.

All plumbing joints shall be permanently sealed by welding or brazing to prevent leakage. Separable self-sealing disconnect joints shall be provided at each of the cap forming machine interfaces to allow removal and installation of the machines without loss of cooling fluid.

(DER) 8. Control Subsystem Requirements. The control subsystem shall include all electrical and electronic control elements not otherwise incorporated in the subsystem modules previously described. This includes the BCU, central multiplexer (MUX), the remote MUX for the assembly subsystems (cord, crossmember, and joining), the power distribution and control module, the data and control link, the power distribution harnesses, and miscellaneous data and control harnesses.

(DER) 9. Software Requirements. Software for the beam builder system shall include applications programs, executive programs, test and checkout programs, and diagnostic programs.

10. Structural Requirements. The beam builder structure shall provide rigid support of all beam builder subsystem modules and elements. The structure shall be a single welded aluminum assembly. Mounting interfaces for all subsystem modules shall be installed as individual pads or brackets to permit final precision machining and shimming required to locate and align each subsystem module within close tolerances. Structural stiffness shall be sufficient to prevent significant deflections which could affect the manufacturing processes in such a way as to distort or cause dimensional errors in the finished beam during fabrication on the ground or in space. The structural assembly shall include all provisions for ground handling, ground transportation, assembly jig interfaces, and in-space handling. (DER)

b. Assembly Jig. The assembly jig shall provide the capabilities to perform plaftorm fabrication functions on the four longitudinal and nine cross beams specified in paragraph 3.2.2.2. (PROP. 1.4.1.2)

1. General. (DER)

(a) The assembly jig will provide the capability to automatically perform all longitudinal beam to cross beam joining functions as each cross beam is positioned. Joining techniques shall be used by the Mission Specialist only for special or unscheduled maintenance operations.

(b) The assembly jig hardware that interfaces with the STS shall be compatible with TBD allocation of STS-provided interfaces specified in Section 3.6.1. (DER)

2. Deployment. The assembly jig shall deploy the beam builder and jig from the stowed position in the cargo bay to the operating position. (DER)

(a) Deployment time will be compatible with the timeline allocation and will take 60 ± TBD minutes. (PROP. 1.4.2.2)

(b) Deployment will be possible with or without the beam builder attached. (DER)

3. Retention. The assembly jig shall retain and guide the longitudinal beams during the cross beam generation process. (PROP. 1.4.1.2)

4. Positioning. The assembly jig shall position and hold the beam builder in any position required to perform beam generation functions. (PROP. 1.4.2.2

(DER) (a) The beam builder positioning will be compatible with the timeline allocation, rotation of TBD deg. in TBD ± TBD minutes about TBD axis, translation of TBD m in TBD minutes along TBD axis.

(DER) (b) The beam builder positioning device shall be removable from the assembly jig on the ground.

(PROP. 1.4.1.2) 5. Positioning and Clamping. The assembly jig will properly position and clamp the longitudinal beams and cross beams for assembly.

(PROP. 1.4.2.1) 6. Translation. The assembly jig will translate longitudinal beams across the face of the assembly jig.

(DER) (a) Beam translation acceleration shall not exceed TBD m/sec^2.

(DER) (b) Translation rate shall be compatible with timeline allocation, and will not exceed TBD m/sec.

(PROP. 1.4.2.1) 7. Process Control. The assembly jig shall provide an executive controller. This Assembly Control Unit (ACU) shall synchronize and control the fabrication functions (except EVA functions) automatically under operator command. In addition, safety interlocks shall be provided for assembly jig deployment and retrieval.

(DER) 8. Illumination. The assembly jig shall provide TBD lighting in excess of natural lighting and/or cargo bay lights described in paragraph 3.6.1.1.c.

(DER) c. Control and Display. Control and display functions for SCAFE fabrication equipment shall be performed by the Orbiter control and display equipment located in the aft flight deck.

d. CCTV and Illumination. Closed circuit TV, RMS TV, payload bay illumination, and RMS illumination shall be provided by the Orbiter as specified in paragraph 3.6.1.1.b and paragraph 3.6.1.1.c.

e. Software. Requirements are TBD.

f. Flight Support Equipment/Interface Hardware. Requirements are TBD.

(DER) 3.7.1.2 Platform (Flight 1)

a. General. Equipment interfacing with the STS shall be compatible with TBD allocated interfaces specified in Section 3.6.1.

Checkout and operational periods while attached to the Orbiter nominally shall not exceed seven days. However, an extended mission shall be considered preferable to a required revisit mission to accomplish all the SCAFE objectives. Operational cycles shall be determined by timelines. Equipment interfaces with the STS shall be comparable with applicable command/control interfaces specified in Section 3.6.1 and space environments specified in Section 3.2.7.1.

Checkout and operational periods while in the free-flying mode shall not exceed 6 months. Operational cycles shall be defined by timelines.

The platform shall not be returned to Earth by the STS.

b. Structural/Platform. Requirements are TBD.

c. Communication/Data. Requirements are TBD.

d. Electrical. Requirements are TBD.

e. Attitude Control. Requirements are TBD.

f. Rendezvous & Docking. Requirements are TBD.

g. Instrumentation/Engineering Experiments. Engineering experiments shall be performed while the SCAFE equipment is attached to the Orbiter and while the platform is operating in a free-flying mode. (DER)

1. General.

(a) SCAFE instrumentation/engineering experiments shall be as defined in paragraph 3.1.3.2.b.2.

(b) EVA or remotely operated mechanical devices shall be used to install or remove instrumentation/engineering experiments, and interconnect cabling.

2. Temperature Instrumentation.

(a) Temperature instrumentation is TBD.

(b) Temperature instrumentation accuracy requirements are TBD.

(c) Temperature instrumentation location requirements are TBD.

3. Deflection Instrumentation.

(a) Deflection instrumentation is TBD.

(b) Deflection instrumentation accuracy requirements are TBD.

(c) Deflection instrumentation location requirements are TBD.

4. Discrete Signals.

(a) Discrete signal requirements are TBD.

(b) Discrete signal levels are TBD.

5. Laser.

(a) Performance/accuracy requirements are TBD.

(b) Laser/target installation requirements are TBD.

6. Free Flight Monitor TV.

(a) Performance/accuracy requirements are TBD.

(b) Installation requirements are TBD.

7. Sun Shade.

(a) Installation requirements are TBD.

8. Command/Control.

(a) Installation/experiment command/control requirements are TBD.

(DER) 3.7.1.3 GFE Experiments.

a. GFE experiments under consideration are specified in paragraph 3.1.3.2.b.3.

b. GFE experiment equipment under consideration is specified in Section 3.1.6.

c. SCAFE structure, equipment, and operations shall be compatible with the performance and operational requirements of the GFE experiments.

d. GFE experiment hardware and software interfaces with SCAFE equipment shall be defined and controlled.

(DER) 3.7.2 GROUND SUPPORT EQUIPMENT (PECULIAR). SCAFE experiment-peculiar ground support equipment (GSE) used at JSC integration site, launch/landing site, or POCC shall be compatible with the requirements of this document. Hardware and software requirements shall be separately specified for each required end item. The following categories shall be considered.

3.7.2.1 Handling and Transport.

a. Dollies

b. Shipping Containers

c. Slings

3.7.2.2 Servicing.

a. Thermal Fluid

b. Battery Fluid

c. Cold Gas

3.7.2.3 Checkout and Maintenance.

a. Electrical Checkout

b. Mechanical Checkout

c. Integration Software

d. Auxiliary Power Supply

e. Ground Heat Exchanger

3.7.2.4 Special (Auxiliary). TBD

3.7.2.5 Simulators/Trainers.

a. EVA Fixture Support Boom

b. EVA Tools

3.7.3 FACILITIES.

TBD

4

VERIFICATION

4.1 GENERAL

TBD

4.1.1 RESPONSIBILITY FOR VERIFICATION. TBD

4.1.2 VERIFICATION METHOD SELECTION. TBD

4.1.3 RELATIONSHIPS TO MANAGEMENT REVIEWS. TBD

4.1.4 TEST/EQUIPMENT FAILURES. TBD

4.2 PHASED VERIFICATION REQUIREMENTS

TBD

4.2.1 DEVELOPMENT. TBD

4.2.2 QUALIFICATION. TBD

4.2.3 ACCEPTANCE. TBD

4.2.4 INTEGRATED SYSTEMS. TBD

4.2.5 PRELAUNCH CHECKOUT. TBD

4.2.6 FLIGHT/MISSION OPERATIONS. TBD

4.2.7 POST FLIGHT. TBD

4.3 VERIFICATION CROSS REFERENCE INDEX

TBD

4.4 TEST SUPPORT REQUIREMENTS

TBD

Program	VERIFICATION CROSS REFERENCE INDEX	Spec No. ________ Dated ________ Page ________

REQUIREMENTS FOR VERIFICATION

VERIFICATION METHOD:

1. Similarity
2. Analysis
3. Inspection
4. Demonstration
5. Test

VERIFICATION PHASE:

A. Development
B. Qualification
C. Acceptance
D. Integrated Systems
E. Prelaunch Checkout
F. Flight/Mission Operations
G. Postflight

N/A - Not Applicable

Section 3.0 Performance/ Design Requirements Reference	Verification Methods								Section 4.0 Verification Requirement Reference
	N/A	A	B	C	D	E	F	G	
Enter in sequence all paragraph numbers of Section 3.		Enter in the applicable phase, the number(s) of the verification method(s) used to verify each item listed in the left hand column.							Enter paragraph number(s) of Section 4 which contain the verification requirements for each performance and design requirement paragraph listed in the left hand column.

Figure 4-1. Verification cross reference index.

4.4.1 FACILITIES AND EQUIPMENT. TBD

4.4.2 ARTICLES. TBD

4.4.3 SOFTWARE. TBD

4.4.4 INTERFACES. TBD

4.4.5 INTERFACE VERIFICATION. The payload accommodation interfaces for the Space Shuttle system have been defined in ICD 2-19001, Shuttle Orbiter/Cargo Standard Interfaces. Interface verification requirements are defined in Space Shuttle System Payload Interface Verification — General Approach and Requirements (JSC-07700-14-PIV-01). The latter document requires that new hardware projects have a verification program planned to ensure that the necessary verification requirements of the respective interfaces are met before the payload is installed in the Orbiter.

Users of the standard payload carriers will assess their payload to determine if new or unique configurations require verification before flight. This assessment and necessary verification will be accomplished in conjunction with the STS operations organization.

Few or no additional verification requirements are anticipated for payloads that are reflown; however, some assessment of the payload should be made to ensure that configuration changes to the payload or cargo do not create a new interface that would require preflight verification.

The term "payload" describes any item provided by the user having a direct physical or functional interface with the Space Shuttle system.

Equipment suitable for interface verification testing is available at the launch site. The cargo integration test equipment (CITE) at KSC is capable of both payload-to-payload interface testing for mixed cargoes and cargo-to-Orbiter testing. The CITE simulates the Orbiter side of the interface in form, fit, and function.

Some equipment at JSC, although designed primarily for STS development, is also capable of payload interface verification. The Shuttle Avionics Integration Laboratory constitutes a high-fidelity electrical simulation of the Orbiter. Another function of this laboratory is flight software verification, especially payload software that is used with the Orbiter computer. The remote manipulator simulator can verify payload deployment, retrieval, and stowage techniques by use of a buoyant inflatable structure to simulate a full-scale payload.

At the completion of the interface verification process, but before the payload is installed in the Orbiter, a certificate of compliance confirming interface compatibility shall be prepared by the using payload organization and submitted to the Shuttle system organization. The certificate of compliance documentation shall include all interface verification requirement waivers, noncompliances, and deferrals; this documentation will become a permanent part of the payload data package.

Payload verification plans shall be submitted to JSC for review and concurrence of the verification methods for safety-critical interfaces. When necessary, the verification methods for the safety-critical interfaces will be negotiated with the responsible payload organization to achieve an acceptable verification that will ensure a safe system. These safety-critical interface verification methods shall be subject to appropriate management control within the Space Transportation System. A verification plan should contain the following information:

a. Scope

b. Applicable documents.

c. Interface verification requirements and methods matrix, identifying specific direct (physical or functional) payload interfaces with the Orbiter and defining the verification method (test, demonstration, etc.) for each specific interface.

d. Safety-critical interface verification method synopsis.

e. Verification requirement waivers (these must be negotiated with JSC).

f. Verification requirement deferrals (i.e., deferral until installation in the Orbiter, until flight, etc.). These deferrals will have to be negotiated in the same way as waivers.

g. Schedule for plan submittal and required approval date.

h. Schedule for payload interface verification testing program and specific dates for safety-critical interface verification tests.